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RELATIONSHIP OF STRAIN AND SIZE AT STOCKING TO SURVIVAL OF LAKE TROUT IN ADIRONDACK LAKES[1]

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ABSTRACT

Experimental stockings of over 206,000 Seneca Lake strain and over 209,000 Upper Saranac Lake strain lake trout were made in nine lakes in northeastern New York from 1964 to 1968. They comprised fall fingerlings, spring yearlings and fall yearlings and were fin clipped to identify the strain and age at stocking. Recoveries of marked fish obtained by gill netting, trap netting, angling and pond reclamation were used to measure survival. A total of 1,812 lake trout from these lakes were examined from 1965 to 1973 among which were 495 that had been stocked for this study. The Upper Saranac Lake strain comprised 94.3 per cent (467), while the Seneca Lake strain constituted 5.7 per cent (28) of the recoveries. Relative survival for all lakes combined was 15.9 : 1 in favor of the Upper Saranac Lake strain. The ratio of survival according to age at stocking (fall fingerlings : spring yearlings : fall yearlings) for all lakes combined was 1 : 9.5 : 8.7. Considering the similar recovery rates for the two yearling groups, lower rearing costs for spring yearlings favor this age group for stocking purposes. Strain was more important than the size of the fish or the season of the year when stocking was done in determining survival. It was concluded that the Seneca Lake strain is not suitable for stocking Adirondack lakes. For lake trout stocking programs in these waters, spring yearlings of the Upper Saranac Lake strain or other Adirondack stock should be used.

Maintenance of viable sport fisheries for lake trout (*Salvelinus namaycush*) in many New York lakes requires partial to complete dependence upon annual plantings of hatchery-reared fingerling and/or yearling fish. Hatchery propagation for this purpose has largely involved two native New York stocks, one originating in the Adirondack region and the other in the Finger Lakes region. Although no geographically consistent divergence in lake trout morphology is known (Lindsey, 1964), variations in spawning habits (Royce, 1951) and suspected differential field performance, as well as marked differences in the water chemistry and morphometric characteristics of lakes in the two regions, prompted segrega-

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tion of the two stocks in hatchery operations. More recently, blood-group typing of lake trout from Cayuga Lake, which are largely of Seneca Lake origin, and lake trout from Upper Saranac Lake has led to tentatively considering these populations to be genetically distinct (Dr. J. E. Wright, Jr., personal communication).

From 1964 to 1973, a comparative study of hatchery-reared lake trout from both these geographic stocks (represented by Seneca Lake and Upper Saranac Lake fish, respectively) was conducted in nine lakes in northeastern New York. It was prompted by declining populations in some Adirondack lakes and by the paucity of lake trout of Finger Lakes origin that were recovered from plantings of marked fish in Raquette Lake as reported by Haskell et al. (1952). One important difference between this study and the earlier work was that the fish tested by Haskell were not all reared under similar conditions (Haskell, 1952; Haskell et al., 1952). The objectives of the present study were: (1) to determine the relative survival and growth of the two strains after being released in Adirondack waters; and (2) to determine the survival of each strain in relation to the size of the fish at the time of stocking. Annual plantings were scheduled over a 4-year period with data for survival and growth to be derived primarily from recoveries by gill net sampling.

METHODS

Eight lakes in the Adirondack region and Millsite Lake in the St. Lawrence plain were selected for study. The Adirondack waters consisted of Third Lake, Fourth Lake, Eighth Lake, Hoel Pond, Little Clear Pond, Polliwog Pond, South Pond and Lewey Lake. The location and morphometric characteristics of these waters and the two brood-stock lakes are given in Figure 1 and Table 1, respectively. Late-summer chemical conditions in the study lakes (Table 2) were determined during August 1966 following techniques given by the American Public Health Asssociation (1955). Dissolved oxygen determinations and water temperature readings were made again in August 1970 but did not indicate major differences from the values observed in 1966. Physical and chemical characteristics of the study lakes, excluding Millsite Lake, are typical of the moderately deep, soft-water lakes associated with lake trout in the Adirondacks. On the other hand, Seneca Lake is extremely deep and the water is alkaline. Millsite Lake tends to be more alkaline than Adirondack waters, but considerably less alkaline than lakes in the Finger Lakes region. It is the only one of the study lakes known to contain opossum shrimp (*Mysis relicta*), an excellent forage for young lake trout.

Lake trout eggs were taken by fish propagation personnel each fall from Seneca and Upper Saranac Lakes and transported to the Warrensburg State Fish Hatchery (Figure 1) for incubation. Young lake trout were

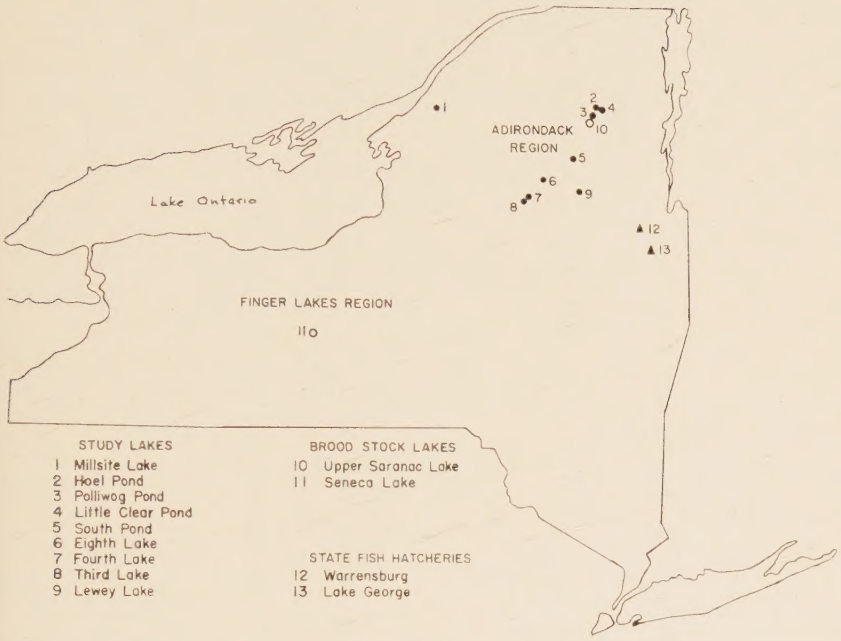

Figure 1. Map of New York State showing location of the study lakes and brood stock lakes as well as the two State fish hatcheries involved in the study.

retained at this facility through the early feeding stage. They were then transferred to the Lake George State Fish Hatchery where they were reared until ready to stock. Rearing waters at these hatcheries are slightly more alkaline than the waters in all the study lakes except Millsite Lake. The waters of both hatcheries had a pH of 6.7 in September 1966. Alkalinity, as calcium carbonate ($CaCO_3$), was 24 ppm at the Lake George hatchery and 30 ppm at the Warrensburg hatchery. Eggs and fish of each strain were kept separate, but they were reared under as nearly identical conditions as practical. Four year classes (1964, 1965, 1966 and 1967) were propagated, marked by fin removal and stocked as fall fingerlings (age 0), spring yearlings (age I) or fall yearlings (age I+).

The stocking program began in October 1964 and terminated in October 1968. Six fin clips were repeated annually to differentiate a year class by strain and age as follows:

Age	Upper Saranac Lake	Seneca Lake
fall fingerling	left ventral	right ventral
spring yearling	left pectoral	right pectoral
fall yearling	left ventral-adipose	right ventral-adipose

Table 1. Morphometric Characteristics of the Study Lakes, Seneca Lake and Upper Saranac Lake

Lake	County	Watershed	Elevation (meters)	Surface area (hectares)	Maximum depth (meters)
		Study Lakes			
Third Lake	Herkimer	Black	520.3	96.8	18.6
Fourth Lake	Hamilton-Herkimer	Black	520.3	879.3	25.9
Eighth Lake	Hamilton	Black	545.9	131.2	23.8
Hoel Pond	Franklin	Champlain	493.5	186.7	26.2
Little Clear Pond	Franklin	Champlain	486.8	145.0	25.3
Polliwog Pond	Franklin	Champlain	485.9	77.8	24.4
South Pond	Hamilton	Raquette	538.6	172.1	15.2
Lewey Lake	Hamilton	Upper Hudson	502.9	144.2	16.8
Millsite Lake	Jefferson	Oswegatchie	91.1	202.1	23.2
		Brood stock lakes			
Seneca Lake	Seneca-Schuyler-Yates	Oswego	135.6	17,265.2	192.9
Upper Saranac Lake	Franklin	Champlain	479.5	2,047.7	30.5

TABLE 2. SUMMER CHARACTERISTICS OF THE STUDY LAKES*

Lake	pH	Total alkalinity (ppm $CaCO_3$)	Hardness (calcium and magnesium) §	Calcium (milligrams per liter)	Dissolved oxygen† (ppm)	Specific conductance (micromhos)	Secchi disk (meters)
Third Lake	6.0-6.8	10.0-12.0	15.0-16.0	5.6- 6.0	2.0- 8.2	48- 54	3.8
Fourth Lake	5.8-6.4	9.0-11.0	15.5-16.0	5.8- 6.4	5.2- 6.0	48- 54	4.1
Eighth Lake	6.4-6.5	15.0-17.0	20.6-21.2	7.4- 7.8	2.6- 9.4	50- 60	6.4
Hoel Pond	5.5-6.0	4.0	9.3- 9.8	3.5- 3.7	7.6-11.0	30- 36	6.4
Little Clear Pond	5.9-6.6	15.0-16.0	16.5-17.0	6.0- 6.2	6.6-12.0	47- 50	5.8
Polliwog Pond	4.6-5.0	2.0- 6.0	6.2- 7.2	2.5- 2.7	1.6-10.8	25- 33	4.6
South Pond	4.9-5.3	2.5- 3.5	9.8	3.1- 3.5	0.3- 4.1	31- 35	3.0
Lewey Lake	5.1-5.7	6.0	11.6	4.0- 4.1	3.3- 5.8	28- 33	3.0
Millsite Lake	6.3-7.6	32.0	41.2-41.6	13.2-14.0	3.4-12.0	100-104	5.2

* Data collected in August 1966.

§ As $CaCO_3$ in milligrams per liter.

† Range is for all waters beneath mid-summer epilimnion.

Spring yearlings were stocked in early May, while fall fingerlings and fall yearlings were stocked in late September or early October. The fish were transported to each lake by truck according to standard hatchery methods, and oxygen was supplied by pressurized cylinders.

During transportation, fingerling and yearling lots were kept segregated until the time of actual stocking in order to minimize predation by the yearlings on the smaller fingerlings. Average transport time from the hatchery to individual lakes ranged from 3.3 hours for Lewey Lake to 5.4 hours for Millsite Lake, and the mean for all lakes combined was 4.3 ($\pm$1.38) hours. A subsequent correlation, based on recoveries of spring yearlings, did not indicate a significant relationship (r=0.32) between transport time and lake trout survival for individual lakes. All the lake trout were stocked from a boat and scattered over deep water. Surface water temperature ranged from 4°-16° C. during spring stockings to 13°-21° C. during fall stockings. Fingerlings were stocked at about twice the rate of spring and fall yearlings to achieve a desired ratio of 2:1:1. Planting densities for each strain ranged from 10 to 16 fingerlings per hectare and from 5 to 6 yearlings per hectare among the nine lakes, resulting in some minor deviations from a 2:1:1 stocking ratio.

Seneca Lake fish averaged consistently larger than Upper Saranac Lake fish at stocking. This size differential resulted in part from the earlier fall spawning period characteristic of lake trout in Seneca Lake where eggs are usually taken from late September to early October, while in Upper Saranac Lake they are taken from mid- to late October. Consequently, because they hatched earlier and began feeding earlier, the Seneca Lake fish averaged larger at any given time. However, Haskell (1952) demonstrated that lake trout from Seneca Lake also have a faster growth rate. Ranges in average total length and number per kilogram for the two strains at stocking are given in Table 3.

Plantings were sampled with standardized gill net gangs each 137.16 meters long and consisting of three sinking-type gill nets. Each gill net was 1.52 meters deep by 45.72 meters long and was composed of six 7.62-meter panels comprising the following stretched-mesh sizes (in centimeters) 3.81, 5.08, 6.35, 7.62, 8.89 and 10.16. The webbing of the nets was constructed of #46 white multifilament nylon twine and was hung

TABLE 3. RANGES IN AVERAGE TOTAL LENGTH AND NUMBER PER KILOGRAM FOR THE TWO STRAINS AT THE TIME OF STOCKING

Age	Total length (centimeters)		Number per kilogram	
	Seneca	Upper Saranac	Seneca	Upper Saranac
Fall fingerling	7.6-9.6	6.9- 7.9	132-192	218-276
Spring yearling	12.4-13.2	10.4-11.4	51- 62	77- 90
Fall yearling	14.7-17.5	12.7-16.5	20- 33	29- 44

on a ⅔ basis. Sampling was begun in the spring of 1965 and was concluded in the fall of 1972. Initially, all lakes were sampled each spring and fall, but in 1968 spring netting was discontinued, and thereafter sampling was confined to the more productive fall period. Additional recoveries of stocked lake trout were provided by non-standard gill and trap netting operations and cooperating anglers as well as from the reclamation of Little Clear and Polliwog Ponds during 1969 and 1973, respectively.

Total lengths of lake trout were measured to the nearest 0.1 inch and weights to the nearest ounce or 0.1 pound. Scale samples were taken from the area between the dorsal fin and lateral line. Stomachs of some dead lake trout and other predatory fishes were preserved in 10 per cent formalin solution for laboratory examination. Young lake trout found in fish stomachs were recorded by strain and age at stocking if fin clips were still identifiable. Two cylindrical live cages, 0.61 meter in diameter by 1.37 meter deep, were used to hold 100 fall yearlings of each strain for a 1-month survival test in Little Clear Pond during 1968. The cages consisted of an aluminum-tubing frame enclosed by 4.8-millimeter-square-mesh nylon netting. They were lowered to lake depths having suitable levels of temperature and dissolved oxygen for young lake trout and were checked periodically to record and remove dead fish.

Age determinations were made for most fin-clipped lake trout recovered during sampling to determine their year of stocking and growth rate. Plastic impressions of at least five scales from each fish were produced with a roller-type scale press on heated, clear cellulose acetate 0.635 millimeter thick. These impressions were magnified to 36X with a micro-projector, and two or three individuals independently aged each fish. Differences in age determinations between scale readers were usually resolved by repeated readings; if not, the scale set was rejected.

Recoveries were enumerated by both strain and age group at stocking, and were transformed to recoveries per thousand stocked in order to calculate and compare the relative survival of the two strains and three age groups. The data were tested for statistical significance by methods given by Snedecor (1956) and Burns (1966). Variations in lake size, sampling effort and recovery techniques between lakes precluded precise inter-lake comparisons of survival. However, sampling and recoveries of lake trout for individual lakes and for all lakes combined provided sufficient information to assess the relative survival of both strains and all age groups.

RESULTS

The results are discussed with respect to the comparative survival of the two strains as well as the different ages of the fish at the time of stocking.

Stocking and Sampling Lakes

Totals of 206,200 Seneca Lake strain and 209,057 Upper Saranac Lake strain lake trout were fin clipped and stocked in the nine study lakes from 1964 to 1968 (Table 4). Minor shortages in the Seneca Lake stock were absorbed by reducing the number of fall yearlings of this strain allocated for Fourth Lake. Consequently, the greatest deviations from the desired stocking ratios of 1:1 for strains 2:1:1 for age groups (i.e., fall fingerling : spring yearling : fall yearling) were confined to Fourth Lake. Gill net sampling and other means (trap netting, angling and reclamation) produced a total recorded catch of 1,812 lake trout from these nine lakes during the period 1965-1973.

Fish of 25 species and two inter-specific hybrids were captured in the study waters by standard gill net sampling from 1966 to 1968. Catch data are given in Table 5 where the species are listed according to the percentage composition of the total catch from all the lakes. Individual lakes contained as few as seven and as many as 17 different fishes vulnerable to capture by the standard gill net. The yellow perch (*Perca flavescens*), white sucker (*Catostomus commersoni*) and brown bullhead (*Ictalurus nebulosus*) were the predominant species in the gill net catch from all lakes combined and in the catches from most individual lakes. Lake trout ranked fifth in the data for all lakes combined and from third to eighth with respect to the individual lakes.

Survival of Stocked Lake Trout

Over 27 per cent (495) of all lake trout examined from the study lakes were marked fish stocked during the study. The Upper Saranac Lake strain comprised 94.3 per cent (467) and the Seneca Lake strain comprised 5.7 per cent (28) of these recoveries (Table 6). Recoveries were concentrated among the 1964, 1965 and 1966 year classes and consisted primarily of 4- to 6-year-old fish. Overall, individuals ranged from 14.7 to 73.4 centimeters in total length and from age I to age VIII at recapture. The greater offshore distribution of younger lake trout and their smaller size apparently allowed a proportionally greater escapement of ages I to III fish from the gill nets used in sampling.

In terms of recoveries per thousand lake trout stocked, the Seneca Lake strain ranged from 0.00 to 0.65 and the Upper Saranac Lake strain ranged from 0.00 to 10.62 for individual lakes. For each strain, the recovery rate was highest in Eighth Lake. Combined returns from all lakes were 2.23 for the Upper Saranac Lake stock and 0.14 for the Seneca Lake stock. Deviations of the recoveries from the 1:1 stocking ratio were consistently in favor of the Upper Saranac Lake strain, the combined recovery ratio for all lakes being 15.9 : 1.

Comparative recoveries according to the age of the fish at the time of

TABLE 4. TOTAL NUMBERS OF MARKED LAKE TROUT STOCKED IN THE STUDY LAKES, 1964-1968

Lake	Seneca Lake strain				Upper Saranac Lake strain			
	Fall fingerlings	Spring yearlings	Fall yearlings	Total	Fall fingerlings	Spring yearlings	Fall yearlings	Total
Polliwog Pond	4,817	2,198	2,192	9,207	4,811	2,193	2,192	9,196
Third Lake	4,976	2,440	2,435	9,851	4,967	2,441	2,433	9,841
Lewey Lake	5,592	3,195	3,199	11,986	5,577	3,193	3,192	11,962
Eighth Lake	8,173	3,638	3,645	15,456	8,170	3,638	3,641	15,449
South Pond	8,161	4,135	4,145	16,441	8,161	4,136	3,828	16,125
Little Clear Pond	8,618	3,942	3,952	16,512	8,616	3,941	3,944	16,501
Millsite Pond	9,850	4,981	4,986	19,817	9,848	4,983	4,978	19,809
Hoel Pond	11,390	5,153	5,151	21,694	11,427	5,150	5,116	21,693
Fourth Lake	44,679	22,026	18,531	85,236	44,606	22,009	21,866	88,481
Total	106,256	51,708	48,236	206,200	106,183	51,684	51,190	209,057

Table 5. Percentage Composition By Species of the Total Gill Net Catch in Each Study Lake During the Years 1966 to 1968

Species	Third Lake	Fourth Lake	Eighth Lake	Hoel Pond	Little Clear Pond	Polliwog Pond	South Pond	Lewey Lake	Millsite Lake	Total
Yellow perch (*Perca flavescens*)	50.77	24.75	3.17	75.25	66.82	62.27	37.69	22.04	..	43.56
White sucker (*Catostomus commersoni*)	22.42	23.76	65.00	5.56	17.38	22.00	56.04	24.99	1.12	27.30
Brown bullhead (*Ictalurus nebulosus*)	3.93	11.02	9.04	1.97	6.88	13.79	2.48	41.64	2.13	11.60
Cisco (*Coregonus artedii*)	..	..	..	5.38	..	..	..	..	69.98	4.42
Lake trout (*Salvelinus namaycush*)	2.32	19.87	6.63	4.48	3.19	1.33	0.80	0.55	3.45	3.46
Golden shiner (*Notemigonus crysoleucas*)	10.69	0.63	7.79	0.36	0.66	..	1.07	1.18	..	2.22
Lake whitefish (*Coregonus clupeaformis*)	0.46	1.26	0.58	2.69	0.88	..	1.07	4.76	..	1.34
Rock bass (*Ambloplites rupestris*)	1.14	3.43	..	..	..	..	..	2.74	10.45	1.34
Pumpkinseed (*Lepomis gibbosus*)	3.67	4.97	..	..	0.88	0.64	0.42	0.30	1.72	1.12
Rainbow trout (*Salmo gairdneri*)	2.17	5.33	3.17	..	0.66	..	..	..	0.10	0.92
Common shiner (*Notropis cornutus*)	2.12	0.63	..	..	0.73	0.04	..	..	..	0.42
Bluegill (*Lepomis macrochirus*)	..	0.27	0.19	..	..	..	..	..	6.29	0.40
Smallmouth bass (*Micropterus dolomieui*)	0.05	0.45	2.02	0.72	..	0.53	..	..	1.12	0.35
Northern pike (*Esox lucius*)	..	..	..	..	..	..	..	1.73	1.93	0.35
Longnose sucker (*Catostomus catostomus*)	..	0.09	1.83	..	1.20	..	..	..	..	0.34
Round whitefish (*Prosopium cylindraceum*)	..	..	..	3.32	0.63	..	..	..	..	0.34
Rainbow smelt (*Osmerus mordax*)	0.05	2.89	..	..	..	..	..	..	..	0.19
Largemouth bass (*Micropterus salmoides*)	..	..	..	..	..	..	..	..	1.72	0.10
Creek chub (*Semotilus atromaculatus*)	..	..	..	0.18	..	..	0.42	..	..	0.08
Brook trout (*Salvelinus fontinalis*)	0.05	0.18	0.29	..	0.03	..	..	0.08	..	0.05
Brown trout (*Salmo trutta*)	0.05	0.27	0.10	..	..	..	..	..	..	0.03
Cutlips minnow (*Exoglossum maxillingua*)	0.10	..	..	..	0.03	..	..	..	..	0.02
Atlantic salmon (*Salmo salar*)	..	0.18	..	..	..	..	..	..	..	0.01
Splake (*Salvelinus fontinalis* × *S. namaycush*)	..	..	0.10	..	..	..	..	..	..	0.01
Stonecat (*Notorus flavus*)*	..	..	0.10	..	..	..	..	..	..	0.01
Cisco × lake whitefish (*Coregonus artedii* × *C. clupeaformis*)	..	..	..	0.09	..	..	..	..	..	0.01
Fallfish (*Semotilus corporalis*)	..	..	..	..	0.03	..	..	..	..	0.01
Total	99.99	99.98	100.01	100.00	100.00	100.00	99.99	100.01	100.01	100.00
Number of fish	1,936	1,107	1,040	1,115	3,170	2,632	2,616	2,373	986	16,975
Number of species	15	17	14	11	14	7	8	10	11	27
Number of gill net gangs	13	20	35	19	18	22	30	26	19	202

* May have been a margined madtom (*Noturus insignis*) as subsequent specimens proved to be the latter.

Table 6. Number of Marked Lake Trout of Each Year Class Recovered From the Study Lakes During the Years 1965 to 1973 Together With Total Recovered and Rate of Recovery According to Strain

Lake	Year class					Total recovered		Rate of recovery§	
	1964	1965	1966	1967	Unknown*	Seneca	Upper Saranac	Seneca	Upper Saranac
Lewey Lake	0	0	0	0	0	0	0	0.00	0.00
Millsite Lake	0	1	0	0	2	1	2	0.05	0.10
South Pond	0	3	3	0	0	0	6	0.00	0.37
Hoel Pond	9	0	0	0	0	1	8	0.05	0.37
Fourth Lake	22	23	22	8	53	6	122	0.07	1.38
Polliwog Pond	7	6	1	1	0	1	14	0.11	1.52
Little Clear Pond	10	45	14	6	0	5	70	0.30	4.24
Third Lake	15	31	30	9	0	4	81	0.41	8.23
Eighth Lake	29	67	63	15	0	10	164	0.65	10.62
Total	92	176	133	39	55	28	467	0.14	2.23

* Marked lake trout, but year class not determined.

§ Number recovered per thousand stocked.

release are given in Table 7. Returns for the Upper Saranac Lake strain predominated in all the study lakes and constituted 96.1 per cent, 93.7 per cent and 94.7 per cent, respectively, of the total recoveries of fish stocked as fall fingerlings, spring yearlings and fall yearlings.

The ratio of the combined recoveries of both stocks (i.e., 51:237:207) deviated significantly from the stocking ratio of 2:1:1 for fall fingerlings, spring yearlings and fall yearlings, respectively. Considerable variation in recovery ratios also occurred between individual study lakes. Variation was most pronounced in Fourth and Eighth Lakes where proportionally more fall fingerling and fall yearling lake trout were recovered than in the other study lakes. Reasons why fall stockings tended to produce comparatively higher rates of return in these two lakes than in the others are not evident. Despite the numerical disparity, the similarity of the ratios between the three age groups in the combined recoveries from all waters for the two strains suggests a consistency in survival. A test for independence indicated that the combined-recovery ratios for the age groups were not likely to have been influenced by the strain factor (chi-square=0.53, 2 d.f., $P>0.75$) and that the recoveries for both strains could be combined to evaluate the success of fingerling and yearling stockings.

The combined recoveries for the two strains in each age group, expressed as recoveries per thousand fish stocks, are given in Table 8 for the lakes studied. Lake trout stocked as fall fingerlings exhibited comparatively low survival in comparison with those stocked as spring or fall yearlings. The highest recovery rate for fall fingerlings was 1.28 in Eighth Lake, while the rate for all lakes combined was 0.24. On the

Table 7. Comparative Numbers of the Two Strains of Lake Trout Recovered From the Study Lakes From 1965 to 1973 According to Age At Time of Release

Lake	Age at time of release								
	Fall fingerling			Spring yearling			Fall yearling		
	Seneca	Upper Saranac	Total	Seneca	Upper Saranac	Total	Seneca	Upper Saranac	Total
Lewey Lake	0	0	0	0	0	0	0	0	0
Millsite Lake	1	1	2	0	1	1	0	0	0
South Pond	0	0	0	0	0	0	0	6	6
Hoel Pond	0	5	5	0	3	3	1	0	1
Fourth Lake	1	15	16	2	27	29	3	80	83
Polliwog Pond	0	0	0	0	13	13	1	1	2
Little Clear Pond	0	3	3	4	46	50	1	21	22
Third Lake	0	4	4	3	49	52	1	28	29
Eighth Lake	0	21	21	6	83	89	4	60	64
Total	2	49	51	15	222	237	11	196	207

Table 8. Comparative Rates of Recovery and Recovery Ratios in the Study Lakes For the Three Age Groups of Lake Trout Stocked

Lake	Rate of recovery (per thousand stocked)			Recovery ratio	
	Fall fingerling	Spring yearling	Fall yearling	Fall fingerling : spring yearling : fall yearling	Spring yearling : fall yearling
Lewey Lake	0.00	0.00	0.00	..	..
Millsite Lake	0.10	0.10	0.00	0.1 : 0.1 : 0.0	0.1 : 0.0
South Pond	0.00	0.00	0.75	0.0 : 0.0 : 0.8	0.0 : 0.8
Hoel Pond	0.23	0.29	0.10	2.3 : 2.9 : 1.0	2.9 : 1.0
Fourth Lake	0.18	0.67	2.05	1.0 : 3.7 : 11.4	1.0 : 3.1
Polliwog Pond	0.00	2.96	0.46	0.0 : 3.0 : 0.5	6.4 : 1.0
Little Clear Pond	0.17	6.34	2.21	1.0 : 37.3 : 13.0	2.9 : 1.0
Third Lake	0.40	10.65	5.96	1.0 : 26.6 : 14.9	1.8 : 1.0
Eighth Lake	1.28	12.23	8.78	1.0 : 9.6 : 6.9	1.4 : 1.0
Total	0.24	2.29	2.08	1.0 : 9.5 : 8.7	1.1 : 1.0

other hand, the corresponding values were 12.23 and 2.29 for spring yearlings, and 8.78 and 2.08 for fall yearlings. Here too, the highest recovery rates occurred in Eighth Lake. For all lakes combined, the recovery ratio (fall fingerling : spring yearling : fall yearling) was 1 : 9.5 : 8.7.

Recovery rates for spring yearlings and fall yearlings in individual lakes were in favor of the spring yearlings except in South Pond and Fourth Lake. Recoveries of these two age groups were subjected to tests of homogeneity (chi-square) to determine if the observed differences were statistically significant (Table 9). In four lakes recoveries were too few to warrant such tests, according to the criteria of Burns (1966). Test results for the remaining five lakes showed that recoveries of spring yearlings were significantly greater than expected in three lakes (Polliwog Pond, Little Clear Pond and Third Lake), that recoveries of fall yearlings were significantly greater than expected in Fourth Lake and that there was no statistical difference between the two age groups in Eighth Lake. Recoveries from all lakes combined failed to show a significant difference, but when the data for Fourth Lake were omitted, a test on the records for the other eight lakes combined showed the recoveries of spring yearlings to have been significantly greater than expected.

Growth of Stocked Lake Trout

Mean total length, standard deviation and sample size of the stocked lake trout recovered in the study waters during the fall at ages II to VII are given, according to strain, in Table 10. Recoveries of fish of the Seneca Lake strain were inadequate for comparing the growth of this stock with that of Upper Saranac Lake stock. For the latter, ranges in mean total length (in centimeters) were: 18.7-23.2 at age II, 21.8-

TABLE 9. COMPARISON, BY CHI-SQUARE TEST OF HOMOGENEITY, OF OBSERVED AND EXPECTED RECOVERIES OF SPRING YEARLING AND FALL YEARLING LAKE TROUT IN THE STUDY LAKES FROM 1965 TO 1973

Lake	Observed recoveries		Expected recoveries		Value of chi-square	Interpretation
	Spring yearling	Fall yearling	Spring yearling	Fall yearling		
Lewey Lake	0	0	..	..	..	Recoveries insufficient
Millsite Lake	1	0	..	..	..	" "
South Pond	0	6	..	..	..	" "
Hoel Pond	3	1	..	..	..	" "
Fourth Lake	29	83	58.41	53.59	31.00*	Recoveries of fall yearlings significantly greater than expected
Polliwog Pond	13	2	7.51	7.49	8.06*	Recoveries of spring yearlings significantly greater than expected
Little Clear Pond	50	22	35.97	36.03	10.99*	" " " " " " " "
Third Lake	52	29	40.55	40.45	6.52*	" " " " " " " "
Eighth Lake	89	64	76.45	76.55	4.16*	" " " " " " " "
Total	237	207	226.34	217.66	1.03	Recoveries of the two age groups not significantly different
All lakes except Fourth Lake	208	124	166.46	165.54	20.85*	Recoveries of spring yearlings significantly greater than expected

* Difference statistically significant: $P<0.05$, 1 d.f.

35.6 at age III, 30.9-46.4 at age IV, 37.2-54.2 at age V, 39.1-57.1 at age VI and 48.0-68.1 at age VII. The size and indicated growth of lake trout varies considerably between individual lakes. Fish of the Upper Saranac Lake strain from Third and Fourth Lakes averaged larger than their counterparts of the same ages in other study waters. The more rapid growth in these two lakes may have been related to use of rainbow smelt (*Osmerus mordax*) as forage. Smelt, although subsequently present in Eighth Lake, were known to have been present only in Third and Fourth Lakes during the entire period of this study.

Factors Affecting Survival

Although sampling variations precluded precise comparisons between the study lakes, it is felt that sampling was adequate for determining the success or failure of the lake trout stocks and age groups used in individual lakes. What factor or combination of factors resulted in the observed differences in success of the two strains were not clear.

The poor success of either strain in Lewey Lake, Polliwog Pond and South Pond may have resulted primarily from a combination of marginal summer water temperature and chemical conditions. These three lakes exhibited extreme combinations of low pH values, low alkalinities and limited quantities of dissolved oxygen in their deeper, cooler waters (Table 2). The tolerance of lake trout to acid water conditions is not well documented; however, Johnson (1975) recently found this species to be less tolerant of acidified water than brook trout (*Salvelinus fontinalis*). Johnson, as well as Butler et al. (1973), presented findings indicating that brook trout in general may begin to suffer some adverse effects in waters below pH 5.0. In Ontario, Beamish and Harvey (1972) attributed the loss of a lake trout population in Lumsden Lake to inceasing levels of acidity and considered 37 other lakes within a pH range of 4.5 to 5.5 to be "endangered" lakes. Accordingly, it seems logical that lake trout stocked in the study lakes may have been under stress and have had their survival limited by various combinations of marginal conditions (low alkalinity, acidity, heavy metals, limited oxygen, undersirable water temperatures), in association with a pH range of 5.0 to 5.5. Ranges for pH levels observed in Polliwog Pond (4.6-5.0), South Pond (4.9-5.3), and Lewey Lake (5.1-5.7) were, in nearly all instances, completely below pH 5.5 during the critical summer period for lake trout.

Heavy predation upon stocked lake trout may have contributed significantly to the poor success of those planted in Hoel Pond, Millsite Lake and South Pond. Lake trout catches from both Hoel Pond and Millsite Lake were predominantly naturally produced fish accompanied by an occasional specimen that had been stocked before the present study. The

Table 10. Mean Total Length of Marked Lake Trout Recovered in the Study Lakes During the Fall At Ages II to VII (1966-1973) According to Strain

Lake*	Age II		Age III		Age IV		Age V		Age VI		Age VII	
	Seneca	Upper Saranac	Seneca	Upper Saranac	Seneca	Upper Saranac	Seneca	Upper Saranac	Seneca	Upper Saranac	Seneca	Upper Saranac
Millsite Lake												
Mean total length§	..	..	..	..	..	35.6	..	..	..	..	..	..
Standard deviation	..	..	..	..	..	..	..	..	..	..	..	..
Sample size	..	..	..	..	..	1	..	..	..	..	..	..
South Pond												
Mean total length§	..	18.7	..	21.8	..	..	..	..	..	..	..	..
Standard deviation	..	± 0.82	..	± 1.80	..	..	..	..	..	..	..	..
Sample size	..	3	..	2	..	..	..	..	..	..	..	..
Hoel Pond												
Mean total length§	20.3	..	..	..	..	..	..	..	..	39.1	..	48.0
Standard deviation	..	..	..	..	..	..	..	..	..	..	..	..
Sample size	1	..	..	..	..	..	..	..	..	1	..	1
Fourth Lake												
Mean total length§	..	..	..	33.4	53.3	46.4	..	54.2	53.8	57.1	..	68.1
Standard deviation	..	..	..	± 0.90	..	± 6.50	..	± 2.30	..	± 3.40	..	..
Sample size	..	..	..	2	1	26	..	31	1	4	..	1

Polliwog Pond												
Mean total length§	..	23.2	21.6	35.6	..	39.2	..	..	..	50.7	..	..
Standard deviation	..	± 4.85	..	± 2.64	..	± 7.12	..	..	..	± 3.48	..	..
Sample size	..	2	1	4	..	3	..	..	..	2	..	..
Little Clear Pond												
Mean total length§	19.6	19.3	..	24.4	28.7	30.9	..	37.2	46.7	..	..	..
Standard deviation	..	± 0.78	..	± 1.71	..	± 2.16	..	± 2.17	..	..	..	..
Sample size	1	5	..	14	1	40	..	10	1	..	..	..
Third Lake												
Mean total length§	20.8	20.1	..	32.2	..	45.8	53.8	49.9	57.0	53.4	..	..
Standard deviation	..	± 1.37	..	± 3.41	..	± 3.15	..	± 4.10	± 3.77	± 3.46	..	..
Sample size	1	4	..	7	..	10	1	37	2	23	..	..
Eighth Lake												
Mean total length§	19.7	21.1	34.3	31.7	34.3	38.3	42.8	44.1	49.9	48.2	61.7	54.6
Standard deviation	± 0.53	± 2.29	..	± 2.52	..	± 1.79	± 0.54	± 1.91	± 4.85	± 2.15	..	± 0.72
Sample size	3	18	1	26	1	35	2	49	2	33	1	2

* Lewey Lake omitted because no marked lake trout were recovered there.

§ In centimeters.

Table 11. Numbers of Marked and Unmarked Lake Trout Captured By All Gear in the Study Lakes From 1965 to 1973 and the Corresponding Catch Ratios*

Lake	Number			Catch ratio (marked:unmarked)
	Total	Marked	Unmarked	
Eighth Lake	244	173	71	1 : 0.4
Third Lake	129	85	44	1 : 0.5
South Pond	22	6	16	1 : 2.7
Polliwog Pond	59	15	44	1 : 2.9
Fourth Lake	554	126	428	1 : 3.4
Little Clear Pond	545	77	468	1 : 6.1
Hoel Pond	150	10	140	1 : 14.0
Millsite Lake	100	3	97	1 : 32.3
Lewey Lake	9	0	9	0 : 9.0
Total	1,812	495	1,317	1 : 2.7

* In this table, marked lake trout comprise fish stocked during the present study, and the "unmarked" category includes both naturally produced fish and lake trout stocked prior to the present study.

higher proportions of non-study lake trout in the samples from these two waters than in those from other study waters are apparent in the marked : unmarked catch ratios shown in Table 11.

Direct evidence of predation on stocked fish by older lake trout already present in a water was found during examination of the stomachs of predatory species taken during sample netting shortly after the plantings were made (Table 12.) These data indicate that cannibalism occurred to some extent in at least seven of the study lakes and that it was substantial in Hoel Pond and South Pond. In addition, 35 per cent of 26 yellow perch stomachs from South Pond contained lake trout.

Data for the relatively small sample of lake trout stomachs from Millsite Lake suggest minor predation there by lake trout. However, reports from anglers indicated that resident lake trout were difficult to catch immediately after spring yearlings had been stocked in the lake, and this was attributed to the abundance of forage provided by such stockings. Since post-stocking sampling usually occurred later in Millsite Lake than in the other study lakes, it is possible that significant predation had already transpired and that the young lake trout taken had been completely digested prior to the sampling. Accordingly, both the limited number of stomachs examined and the later sampling periods may have been the reason why positive evidence of the suspected heavy post-stocking predation in Millsite Lake was not obtained.

Recovery ratios of the Seneca Lake strain to the Upper Saranac Lake strain of lake trout over time indicated that the Seneca Lake stock disappeared rapidly during the first year following stocking. Live-cage tests of both strains in Little Clear Pond failed to produce biological or statistical evidence of any differential mortality in adjusting to this water

Table 12. Occurrence of Young Lake Trout in the Stomachs of Predatory Fish Taken in the Study Lakes Shortly After the Lake Trout Had Been Planted, 1965-1968

Species	Range in total length (centimeters)	Number of stomachs containing young lake trout*										Percentage containing lake trout
		South Pond	Hoel Pond	Mill-site Lake	Eighth Lake	Polliwog Pond	Third Lake	Little Clear Pond	Lewey Lake	Fourth Lake	Total	
Lake trout	30.5 - 78.0	3(5)	14(25)	1(6)	3(15)	2(14)	1(8)	3(69)	0(2)	0(18)	27(162)	16.7
Northern pike	34.3 - 70.3	..	..	1(7)	..	..	..	..	0(11)	..	1(18)	5.6
Yellow perch	18.0 - 35.8	9(26)	0(23)	..	..	3(95)	0(23)	0(105)	0(1)	0(29)	12(302)	4.0
Rainbow trout	19.0 - 46.2	..	..	..	0(20)	..	0(10)	0(10)	..	0(7)	1(47)	2.2
Brown trout	61.5	..	..	..	..	0(1)	..	..	..	..	0(1)	0.0
Largemouth bass	26.9	..	..	0(1)	..	..	..	..	..	..	0(1)	0.0
Brook trout	35.1 - 36.1	..	..	..	0(1)	..	..	..	0(1)	..	0(2)	0.0
Rock bass	17.8 - 28.2	..	..	0(10)	..	..	0(2)	..	0(10)	..	0(22)	0.0
Smallmouth bass	20.3 - 41.1	..	0(7)	..	0(9)	0(16)	..	..	..	0(3)	0(35)	0.0
Total		12(31)	14(55)	2(24)	3(45)	5(126)	1(43)	4(184)	0(25)	0(57)	41(590)	xxxx
Percentage containing lake trout		38.7	25.5	8.3	6.7	4.0	2.3	2.2	0.0	0.0	7.0	xxxx

* Figures in parentheses represent number of specimens.

during a 1-month period (chi-square=0.93, 1 d.f., $P=>0.25$). Although there was opportunity for outmigration through the outlets of most of the study lakes, no evidence of interlake movement was found other than the passage of fish of the Upper Saranac Lake strain between Third and Fourth Lakes. Pycha and King (1967) reported that success or failure of some lake trout plantings in Lake Superior was determined within 2 or 3 months after planting. Possibly a similar time period was required for these two New York stocks to establish their success or failure. Contents of the stomachs of predatory fish taken in the study lakes shortly after lake trout stocking revealed a higher prevalence of Upper Saranac Lake strain than of Seneca Lake strain lake trout (2.3 : 1). Unless selective predation on the Seneca Lake fish occurred immediately at stocking, it is unlikely that predation alone limited the survival of this strain in all study waters.

Stockings of the Seneca Lake strain in New York waters outside the Finger Lakes region have been more successful in comparatively large, deep non-mountain lakes than in the more elevated, shallow Adirondack lakes. Moderately alkaline to relatively alkaline waters such as Lake Champlain (41-42 ppm $CaCO_3$, pH 7.5-8.1) and Otsego Lake (100-200 ppm $CaCO_3$, pH 8.0) appear to be most favorable for the survival of this strain. However, the Maine Department of Inland Fisheries and Game has been successful in stocking the Seneca Lake strain in Sebago Lake (104 meters deep) where the alkalinity (2-10 ppm $CaCO_3$) and pH (6.4-6.6) of the water are similar to those of the Adirondack study lakes (S. DeRoche, personal communication). Perhaps relatively shallow depths and/or various chemical conditions (acidity, heavy metals) in association with the poorly buffered, low-alkaline waters characteristic of Adirondack lakes may have largely precluded successful stocking and establishment of the Seneca Lake strain in the lakes studied.

DISCUSSION

Recoveries of stocked lake trout from the study waters were highly in favor of the Upper Saranac Lake strain over the Seneca Lake strain, and the data were interpreted to have represented a survival ratio of 15.9 : 1. Strain alone was apparently more critical initially in determining survival in these waters than either the size of the fish at stocking or the season of the year when the stocking was done. Recoveries of comparable numbers of marked lake trout from Fourth Lake, Little Clear Pond, Third Lake and Eighth Lake provided the bulk of the information about the two strains and exerted the greatest influence on the pooled data from all the lakes. These results agree with the findings of Haskell et al. (1952) for Raquette Lake, another Adirondack lake trout water. In that instance, recoveries of stocked lake trout on spawning beds

produced a ratio of 23.5 : 1 in favor of fish derived from native Raquette Lake stock over fish of the Seneca Lake strain.

Findings of the present study indicate that, if the Seneca Lake strain were used for stocking Adirondack waters, about 16 times as many fish would be required to achieve results comparable to those expected from use of the Upper Saranac Lake strain. Since requirements for rearing the two strains are not substantially different, the cost and space needed for producing Seneca Lake stock would be increased proportionally. Accordingly, from both a biological and an economic viewpoint, the Seneca Lake strain is not practical for use in the management of Adirondack lake trout waters.

Pooled recovery ratios of 1 : 9.5 : 8.7 from the study waters for fall fingerlings, spring yearlings and fall yearlings, respectively, show that both groups of yearlings were decidedly superior to fall fingerlings for stocking Adirondack waters. Results favoring yearlings over fingerlings for lake trout stocking have also been recorded for Cayuga Lake, Lake Superior and certain Maine lakes. Webster et al. (1959) found the ratio of yearling to fingerling survival to be 4:1 for lake trout stocked in Cayuga Lake. Later, Schuler (1969) reported returns of 3:1 to 4:1, also favoring yearlings over fingerlings, in the same lake. Buettner (1961) indicated a survival ratio of roughly 9-10 : 1 for yearlings over fingerlings among lake trout stocked in Lake Superior. Pycha and King (1967) reported ratios of 3.9 : 1 and 6.7 : 1 favoring yearlings over fingerlings in returns from lake trout stocked in the Wisconsin and Michigan waters, respectively, of Lake Superior. Spring yearlings outnumbered fall fingerlings by nearly 17 to 1 in fish taken by anglers at one Maine lake (Anderson, 1962).

Webster et al. (1959) compared costs for producing fingerling and yearling lake trout in New York State hatcheries and found that four fingerlings could be reared for the same cost, in terms of feed and space, as one spring yearling. They concluded that yearlings stocked in Cayuga Lake would have to achieve "substantially more than fourfold predominance" to justify rearing them instead of fingerlings. In the present study of Adirondack lakes, yearlings exhibited a more than eightfold (8.7-9.5) advantage over fingerlings in survival. The comparative costs of stocking lake trout of different ages in Adirondack lakes were calculated, based on the rates of recovery recorded during this study and a rearing cost of $5.51 per kilogram (Table 13). With respect to the observed values in this table, although the recovery rates were derived from data for both strains, the other figures represent the Upper Saranac Lake strain. Despite the relatively low cost of rearing, the low survival of fall fingerlings would make it necessary to stock 9.5 times as many of them as of the spring yearlings to achieve comparable numer-

Table 13. Comparative Cost, In Terms of Equivalent Numerical Survival, of Stocking Lake Trout As Fall Fingerlings, Spring Yearlings or Fall Yearlings

Age of stock	Observed values				Calculated values			
	Number of fish per kilogram*	Rearing statistics per 1,000 fish		Recovery per 1,000 stocked†	Stocking requirements for equivalent numerical survival			Relative cost factor
		Weight (kilograms)	Cost (dollars)		Number	Weight (kilograms)	Cost (dollars)	
Fall fingerling	247.0	4.0	22.04	0.24	9,500	38.0	209.38	3.2
Spring yearling	83.5	12.0	66.12	2.29	1,000	12.0	66.12	1.0
Fall yearling	36.5	27.4	150.97	2.08	1,100	30.1	165.85	2.5

* Median of range of averages for fish of Upper Saranac Lake strain stocked during this study.

§ Based on rearing cost of $5.51 per kilogram for progeny from eggs obtained from wild stock (R. H. Griffiths, personal communication). In New York State's hatchery system, production costs for a given species or strain are derived from the annual cost of operations and the total weight of fish produced.

† From Table 8.

ical survival. The essentially equal rates of recovery for spring yearlings and fall yearlings stocked indicated no over-all advantage to be gained from rearing the larger and over twice as costly fall yearlings. Therefore, the results of this study indicate that, for stocking lake trout in Adirondack waters, the spring yearling age group would be the best to use. Making the most efficient use of hatchery-reared fish becomes increasingly important when the supply available for propagation is limited as is the case with respect to lake trout of Adirondack origin.

In summary, results of this study lead to the conclusion that lake trout of Seneca Lake origin are not a satisfactory substitute, either biologically or economically, for those of the Upper Saranac Lake strain in the management of Adirondack lakes. Use of other Finger Lakes stock or lake trout from other sources outside the Adirondacks should also be regarded with caution in managing Adirondack lake trout waters. It is also concluded that spring yearlings are superior to either fall fingerlings or fall yearlings and that their use in lake trout stocking programs is justified by savings both in numbers of fish required and in rearing costs. Accordingly, it would seem that a program of stocking spring yearling lake trout has general application in Adirondack waters and elsewhere in New York (Plosila, 1976). Disappointing returns for both strains in Lewey Lake, Millsite Lake, South Pond, Hoel Pond and Polliwog Pond indicate that stocking hatchery-reared lake trout in these waters is a questionable venture under present conditions. However, recoveries for the Upper Saranac Lake strain from Little Clear Pond, Third Lake, Fourth Lake and Eighth Lake were sufficiently high to warrant continued stocking with fish of this strain, or other Adirondack strains if necessary.

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SELECTIVE BREEDING OF TROUT FOR RESISTANCE TO FURUNCULOSIS[1]

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ABSTRACT

Results, subsequent to those previously published, concerning efforts to develop furunculosis resistance in strains of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) are reported. Crossing resistant strains produced no further significant increase in the level of resistance, so techniques employing individual matings were attempted. Limited field testing of resistant strains was generally encouraging but suggested that a selected furunculosis-resistant strain of brook trout may be more susceptible to gill disease. Project setbacks from flooding and extraneous diseases, as well as difficulties in efforts to field test resistant strains, are discussed.

A previous report (Ehlinger, 1964) covered the first 10 years of research relating to selective breeding of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) primarily for resistance to furunculosis. Data presented here covered the period from 1963 through March 31, 1972 when the project was terminated.

Pertinent findings in the first report included development of refined laboratory tests to evaluate resistance to furunculosis. These clearly indicated a level of disease resistance in some strains of both species. It was noted, however, that comparisons of resistance levels among the best strains were not always consistent from year to year. Reasons for this could have been use of different strains of *Aeromonas salmonicida* (the etiological agent of furunculosis), possible mutation of some bacterial strains through reuse and storage, and unavoidable year-to-year variations in cultural methods and diet.

Limited field testing of selected strains of trout showed evidence of better survival when they were exposed to natural epizootics of the disease as it occurred in hatcheries. Growth and general behavior of the resistant strains appeared to be at least comparable to that of the domestic hatchery strains. Additional appraisal was considered necessary, however, to reliably determine their economic worth.

Before proceeding to the specific areas of research undertaken after the earlier period of study, some of the data collected during that period concerning the resistance of fingerling trout are given to illustrate the degree of resistance that had been developed in selectively bred lines. The

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[2] Retired.

Table 1. Comparison of Selectively Bred Strains of Brook Trout and Brown Trout That Performed Best With New York Hatchery Domestic Strains and With Strains From Non-State Hatcheries With Respect To Survival Following Exposure to Furunculosis, 1964

Species and strain		Survival (average of four tests)*
Brook trout		
45-62b	(selectively bred)	167.0
64R	(State hatchery stock)§	101.9
64X	(non-State hatchery stock)	79.2
Brown trout		
9G-62b	(selectively bred)	79.0
64R	(State hatchery stock)§	11.9
64Y	(non-State hatchery stock)	0.0

* For brook trout: values expressed at ST_{50} hours (time at which 50 per cent of fish were surviving in controlled laboratory exposure); LSD ($P=0.05$) = 22.4 hours.

For brown trout: values expressed as percentage survival after 7-day exposure; LSD ($P=0.05$) = 15.5 per cent.

§ Control.

testing techniques used were described by Ehlinger (1964). In Table 1, the bred strains that performed best are compared with two strains (64X and 64Y) imported from non-New York State hatcheries, as well as with two New York hatchery domestic strains which were used annually as control fish to determine comparative resistance levels. The control strains had undergone no intentional selection but could have developed some inherited tolerance from occasional exposure to the disease at the brood trout hatchery. The data for brown trout are expressed as percentage of survival because in the more resistant strains mortality did not approach 50 per cent of the total lot.

Near the end of the period covered in the first report, improvement in resistance to furunculosis had reached a point where year-to-year change was hardly measurable. The best of the resistant strains at that time had been derived from several cycles of crosses between strains that showed the most resistance, followed by mass selection under exposure to *A. salmonicida*. Since little is known concerning the genetics of resistance to the disease, it appeared possible that within-strain variation existed either for resistance or for genetic factors that modify its expression. It was decided that mating selected pairs within resistant strains might produce a higher level of resistance than cross breeding between strains. Possible undesirable consequences of this restrictive method (accentuation of undesirable secondary characteristics) were recognized, but it was attempted because it was also possible that desirable attributes such as increased fecundity, high egg and fry viability, coloration and body conformation could be improved by using it. Mass selection in the best

strains already developed was continued in order to maintain resistance levels and to provide eggs for their testing or use in selected hatcheries.

BREEDING METHODS

Parents for individual crosses were selected from better-performing strains. Median-sized fish with good body conformation, coloration and markings were chosen. Ages of parents were generally 2 years (or second spawning) for brook trout, and 2 or 3 years for brown trout. These individual matings were designated "IDM", and the progeny were labeled IDM prefixed with a numeral. The number of individual matings that could be cultured and tested for resistance to furunculosis was limited by the available space and the difficulties in handling small lots.

In the fall of 1963, six brown trout and four brook trout IDMs were made, and the resultant fingerlings were carried through 1964. Data on performance of the brook trout progeny showed no improvement in disease resistance. But, furunculosis resistance of fingerlings from two matings of brown trout from a high-ranking strain did appear promising. One of these was retained and spawned at maturity in the fall of 1966. The progeny also attained an excellent rating. Unfortunately, this strain was one of those lost in the severe flood of May 20, 1969.

In the fall of 1965, a system was started that would allow comparison of the parents used in individual matings on the basis of their progeny's performance for resistance. With limited available space, this appeared to be the best method for identifying differences among individual parents.

Four gravid, acceptable females were selected from a high-ranking, disease-resistant strain. Each was stripped into individual pans, and both the eggs and the brood fish were carefully marked for future identification. Milt from four ripe males of the same strain was then pooled and used to fertilize the individual batches of eggs. Comparative data for the different groups of progeny in resistance tests would indicate the best female parent. Conversely, eggs from four females were pooled and milt from four selected males was used to fertilize separate lots of the pooled batch. Again, egg lots and individual males were carefully marked, and resistance tests would indicate the best-performing male. In the next breeding season, the best male and female would be mated to provide a nucleus for a new strain.

This system was employed in 1965, 1966 and 1967, but unanticipated difficulties were encountered. The greatest problem was failure of parents to survive until the next spawning season; one or both of those intended for a desired mating usually expired before it could be made. Attempts to correct this by using first-spawning fish with greater potential for survival were not successful. Particularly with brook trout, egg

quality or viability was so depressed and eggs numbers so low that few fingerlings were available for resistance testing. Difficulties possibly could have been partially remedied by selecting a greater number of females to furnish pooled eggs and using the progency only to test individual males. Nevertheless, this method of selection was discontinued in 1968.

TESTING STRAINS PRODUCED

Basically, the purpose of this project was to provide resistant stock for use by hatcheries, both within the State and outside the State, having furunculosis problems. Certain principles were recognized in connection with this.

1. If disease-resistant stock is not continually or at least periodically exposed to the disease, reversion to a less-resistant status is probable. Although experimentation indicated that resistance was maintained in fish one generation removed from laboratory exposure to furunculosis, this would not necessarily continue. Hatchery use of a resistant strain should, therefore, include planned periodic replacement from a brood stock maintained to keep resistance at a high level.

2. Continued exposure of brood stock is necessary because genetic changes occur with each sexual generation; in the absence of the disease, normal hatchery production methods may select against resistance. Maintenance of brood stock under planned exposure to disease is an integral and necessary part of using genetically improved strains in a hatchery program.

3. There is also a distinct probability for strains of *A. salmonicida* to vary in virulence and pathogenicity and for the prevalence of different strains to vary over time. New genetic variants are also possible. A brood stock continuously exposed to multiple sources of disease innoculum (in the present work, 25 geographic sources were used in developing furunculosis resistance) has the best chance of continuing the achieved level of resistance.

Hatcheries in several states close to New York were contacted regarding their furunculosis problems and their interest in testing selectively bred stock on a comparative basis. Simple guidelines were proposed. It was suggested that treatment for furunculosis in the form of internal medicine be withheld (1) until disease was positively diagnosed by a qualified person or (2) until mortality became so extensive that control measures were deemed economically proper. If used, treatments (whether prophylactic or therapeutic) for gill disease, ectoparasites, fungus or whatever would follow normal procedures for their domestic stock. Re-

sponses were discouraging. Furunculosis was admitted to be a problem, but often there was no enthusiasm to try out a new strain of fish. The reason for a negative attitude may have been reasonably effective control of the disease through medication, an aversion to collecting data or a reluctance to use a separate strain that would interfere with normal production hatchery routine. In consequence, good test situations were limited, and eggs of resistant stocks were supplied in some cases under very questionable circumstances. Reported results were often meager and frequently had to be requested.

One cooperative group supplied valuable information on susceptibility to gill disease in the selectively bred strains of brook trout which they tested. Their observations in 1965, 1966, 1967 and 1968 indicated a deficiency in the bred strains, and testing in in-State hatcheries also suggested it. Unfortunately, in both cases these were observations only, and no specific comparison with a control strain was made. Laboratory appraisal of this deficiency was not possible through deliberate induction because the etiological agent of the disease has not been clearly defined. A type caused by a diet deficient in pantothenic acid (Wolf, 1945) apparently did not apply here.

Eggs from a resistant strain of brook trout were shipped to another cooperating state in the fall of 1964. Resultant data for fingerlings and yearlings through May 1966 indicated excellent resistance to furunculosis. Populations of domestic strains in ponds above them had to be treated to meet production needs, while the selectively bred strain received no medication. On the negative side, a high susceptibility to gill disease was observed.

The same unit tested a brown trout strain as fingerlings in 1966 and as yearlings in 1967. Growth and resistance to furunculosis were reported as excellent. When compared with their own domestic stock as 2-year-olds in a pond stocked for public fishing, they were found to be somewhat better in survival, growth rate and catchability.

Personnel in another state reported the selectively bred strains from New York to be more resistant to furunculosis and kidney disease than their own stock but more susceptible to infectious pancreatic necrosis.

Some of the limited testing within the State was encouraging with respect to furunculosis resistance in brook trout, but the indications that these strains were more susceptible to gill disease served to deter any plans to totally incorporate furunculosis-resistant strains as brood stock. It was felt that a sustained, comprehensive and controlled screening in several hatcheries should be done before replacing any existing brook trout brood stock.

A testing program for a furunculosis-resistant strain of brown trout was carried out in 1968. The results are given in Table 2. Hatchery conditions

TABLE 2. COMPARATIVE PERFORMANCE OF A SELECTIVELY BRED STRA IN OF BROWN TROUT AND A NEW YORK HATCHERY DOMESTIC STRAIN AS RECORDED AT FIVE STATE HATCHERIES IN 1968

Month	Strain*	Bath				Catskill				Lake George			
		Number per pound	Conversion factor§	Growth†	Mortality (per cent)	Number per pound	Conversion factor§	Growth†	Mortality (per cent)	Number per pound	Conversion factor§	Growth†	Mortality (per cent)
January	RL	1,785.0	2.2	82.0	1.2	..	..	..	..	..	..	..	..
	RE	2,000.0	2.6	73.0	2.5	..	..	..	..	..	..	..	..
February	RL	1,137.0	3.9	66.0	2.8	..	..	..	..	..	..	..	..
	RE	1,200.0	3.8	63.0	5.1	..	..	..	..	..	..	..	..
March	RL	556.0	2.8	81.0	2.6	..	..	..	..	..	..	..	..
	RE	593.0	3.1	71.0	5.4	..	..	..	..	..	..	..	..
April	RL	278.0	2.5	102.0	1.3	..	..	..	..	..	..	..	..
	RE	298.0	2.7	95.0	4.4	..	..	..	..	..	..	..	..
May	RL	135.0	2.4	105.0	0.46	..	..	..	..	..	..	..	..
	RE	138.0	2.2	117.0	0.6	..	..	..	..	..	..	..	..
June	RL	66.0	2.3	92.0	0.3	79.0	1.55	73.0	1.1	218.0	5.67	35.0	0.15
	RE	78.0	3.3	54.0	0.4	96.0	2.24	61.0	0.6	176.0	6.52	28.0	0.21
July	RL	41.0	3.1	61.0	0.15	36.0	1.38	117.0	0.3	60.0	1.07	264.0	0.02
	RE	47.0	3.0	66.0	0.26	38.0	1.20	149.0	0.3	65.0	1.33	168.0	0.03
August	RL	21.0	1.3	99.0	0.7	22.0	1.68	67.0	0.4	37.0	1.7	62.0	0.08
	RE	26.0	1.7	80.0	0.7	23.4	1.6	63.0	0.4	34.0	1.3	91.0	0.12
September	RL	15.2	1.9	47.0	0.1	14.0	1.0	65.0	0.2	24.0	1.89	54.0	0.05
	RE	18.5	1.9	43.0	0.07	14.8	1.17	53.0	0.4	22.0	1.72	54.0	0.05
October	RL	..	..	..	..	11.0	1.8	22.0	0.1	..	..	..	..
	RE	..	..	..	..	11.5	2.4	14.0	0.2	..	..	..	..
November	RL	..	..	..	..	9.3	1.5	20.0	0.1	..	..	..	..
	RE	..	..	..	..	9.5	1.4	22.0	0.1	..	..	..	..

Month	Strain*	Randolph				Rome			
		Number per pound	Conversion factor§	Growth†	Mortality (per cent)	Number per pound	Conversion factor§	Growth†	Mortality (per cent)
January	RL	1,550.0	3.7	47.0	1.2	523.0	5.1	87.0	0.5
	RE	1,600.0	10.8	36.0	12.6	485.0	5.0	82.0	1.8
February	RL	1,100.0	3.5	43.0	1.1	309.0	3.8	67.0	0.5
	RE	1,160.0	7.9	34.0	6.3	264.0	3.0	82.0	0.7
March	RL	775.0	3.5	39.0	0.8	218.0	5.3	41.0	0.6
	RE	916.0	14.0	26.0	0.7	166.0	3.7	57.0	1.1
April	RL	345.0	2.5	113.0	3.4	118.0	2.6	88.5	0.2
	RE	500.0	3.8	51.0	19.0	96.5	2.7	73.0	0.5
May	RL	175.0	2.7	75.0	4.0	80.5	3.6	46.0	0.8
	RE	221.0	1.8	105.0	9.0	61.6	2.78	56.5	0.15
June	RL	88.0	1.5	77.0	0.6	55.7	4.57	39.0	0.2
	RE	106.0	3.3	49.0	2.0	46.9	6.14	25.0	0.3
July	RL	48.5	1.6	77.0	1.6	28.5	2.0	95.0	0.25
	RE	50.4	1.3	108.0	0.9	24.7	2.1	89.0	0.2
August	RL	25.0	1.2	96.0	0.4	15.2	1.8	89.0	0.16
	RE	25.9	1.1	91.0	2.0	12.9	1.8	91.0	0.15
September	RL	16.2	1.3	52.0	0.4	9.6	1.5	59.5	0.12
	RE	16.6	1.7	39.0	0.5	8.3	1.6	56.0	0.08
October	RL	13.0	1.8	25.0	0.04	..	1.2	40.0	0.4
	RE	12.5	1.6	28.0	1.2	..	1.8	32.5	0.4
November	RL	11.2	1.9	15.0	0.07	..	..	..	..
	RE	9.8	1.4	27.0	0.2	..	..	..	..

* RL = selectively bred strain 9-66b; RE = domestic strain from Randolph Hatchery.
§ Pounds of feed required for an increase of 1 pound in trout weight.
† Percentage increase in weight.

and production commitments necessarily placed certain limitations on the amount of data accumulated. The selectively bred strain used was designated RL, and the control strain, which New York had used for many years, was designated RE. It was perhaps "unfortunate" that no real outbreak of furunculosis occurred at any of the five participating hatcheries during the test period so the selected strain could have been rigidly appraised for the value of its prime attribute. At two of the three hatcheries that reared them, there was some indication that mortality among early fingerlings was less for those of the RL strain than for the RE fish.

On the basis of these tests it was concluded that brown trout of selectivly bred strain RL-9 would perform equally as well as the previously used strain, and it was contemplated that eggs of this premium strain would be supplied to the State's brood trout hatchery on a continuing basis to provide some furunculosis protection. Unfortunately, selective breeding was discontinued in 1972 following a series of events that interferred with the normal succession of lines and to an extent resulted in the loss of genetic materials accumulated or developed over the span of the project.

ADVERSE EVENTS

Nevertheless, selective breeding programs for salmonids and other species are likely to be undertaken again in the future, and it is important that the knowledge and experience gained in the present work not be lost. Similar principles will apply and similar hazards will be encountered in future programs. The following account of the difficulties that occurred during the final phase of the project is given for the benefit of those planning future work of this sort.

Flooding

In May 1969 a major catastrophe to the project was caused by flood conditions in the upper Mohawk River. Rising water flowed back up through the pond drains. Overflows occurred between rearing ponds and overran dividing screens within ponds, resulting in an apparent mixing of breeding strains. After weighing the damage carefully, it was deemed necessary to eliminate all stocks since none could be assumed pure, although marking or tagging some individuals within different strains would have at least partially reduced the losses.

The impact of this flood would have been even more devastating had not the fingerling populations of the year—progeny of most preferred strains—been in rearing troughs above flood level. Most of the premium disease-resistant strains could be continued from this generation. The greatest effect of the flood was the interruption of normal breeding succession; there were no eggs for brown trout distribution commitments in the falls of 1969 and 1970 or for brook trout commitments in 1969.

Epizootic of Infectious Pancreatic Necrosis

Misfortune struck again in the spring of 1971. Fingerling brook trout had developed normally in the laboratory rearing troughs until late January. At this time, mortality increased in a single strain, and behavior patterns suggested the presence of infectious pancreatic necrosis. This was later confirmed by both histological and virological techniques. Although the suspect strain was isolated, infection was not arrested, and fingerlings of all strains subsequently contracted the viral infection and had to discarded.

Since the nature of this infection may implicate the parents (adults may act as carriers and readily transmit it to offspring), all the existing strains of brook trout breeders were screened for the virus. The results of this examination proved negative and consideration was given to other infection possibilities, but no conclusion was ever reached. A year class was lost, but all the parents remained so that eggs could be taken from them as second spawners in the fall of 1971. A thorough disinfection of all facilities and equipment that had even remotely come in contact with the diseased fish was painstakingly carried out. The vulnerability of genetic stocks maintained at a single facility was clearly demonstrated. The most careful of sanitation measures are not adequate insurance if stocks are maintained at a single site.

Fungus Epizootic

Despite these setbacks, the project was continued with major emphasis on maintaining two strains of brown trout and possibly three of brook trout under exposure to multiple strains of *A. salmonicida* to assure a continuing high level of resistance to furunculosis. Then, in late May of 1971, a third catastrophe struck the surviving lots of fish in the ponds. Mortality suddenly rose sharply from a fungus infection in the 2-year-old stocks. Overt symptoms were heavy infestations developing as patches on the skin and frequently spreading to cover almost the entire body of an individual. Death often occurred before the time of copious dissemination, but afflicted areas were always obvious. An attempt was made to determine the relative frequency of infection at common focal sites, but definite patterns were not apparent. At times a preponderance occurred in the head area only, while at other times the peduncle or the dorsal areas surrounding and including the dorsal fin would be involved.

Body fungus is not uncommon in hatchery fish, but it usually is restricted to a minimum number of individuals in any given population and is normally associated with some primary cause. Causes may include bruising from handling, localized lesions resulting from injury or disease, integumental parasites of various forms, or possibly a debilitating sys-

temic infection rendering the fish totally susceptible and vulnerable to the numerous fungus spores common in all waters.

While it was observed that the 1971 fungus infection was becoming more or less widespread in the ponds, it was at first considered a probably desirable circumstance in the selective breeding program for disease resistance, and a sustained and detailed examination of the condition was not made immediately. Cursory examination revealed no apparent primary cause, and it was felt that in a relatively short time it would clear up due to natural or acquired resistance in the survivors. Mortality, however, continued to rise at an increasing rate and, by the end of June, 30 per cent of a high-ranking strain of brook trout had died as a result of this epizootic.

Efforts were made to determine the eitology of the disease, and several futile treatments were attempted with accepted and normally effective fungicides. Other fish pathologists were contacted and the literature was reviewed in an attempt to interpret and suppress the infection. W. W. Scott, head of the Botany Department of Eastern Illinois University who has done considerable research on fish fungi, examined material sent to him and identified the organism as belonging to the genus *Saprolegnia*. Lack of sexual stages made it impossible to determine the species, but the asexual forms resembled *S. parasitica*.

Study of the pathogenesis of the disease was directed to two areas: (1) *Aeromonas liquifaciens*, a well-known fish pathogen of varying virulence, was isolated in limited numbers from subcutaneous tissues underlying fungus patches and/or kidneys and was encountered in perhaps 70 per cent of all the fish examined; (2) a dry, closed-formula, pellet diet without a meat supplement had been fed for a period of 7 months prior to the outbreak. The latter procedure had not been previously used at the site, but it was considered to be proper and necessary since most hatchery systems do feed 100 per cent pelleted food. Unique differences in dietary requirements for all furunculosis-resistant strains of trout are not very probable.

Toward the end of June 1971, mortality declined along with incidence of the fungus. This could not be associated with any treatment and was probably connected with the increase in water temperature. Water temperatures during the winter were in the 30's (F.), reached 41.5° F. at the end of April, and at the onset of the epizootic were near 49°-50° F. The decline in mortality occurred at around 54°-55° F. As water temperatures continued to climb, mortality again increased, but due to furunculosis and not fungus.

In the first week of October, as declining water temperatures reached 58° F., the fungus infection gradually reappeared while losses from furunculosis declined. It was more prevalent at first among the brook

trout but later became equally as devastating to the brown trout. Brown trout losses continued to be high throughout November and did not taper off until mid-December when temperatures declined to around 37° F. Brook trout losses decreased earlier, probably due to the previous drastic reductions in population numbers.

Although a determined effort was made to solve many aspects of the disease problem, nothing can be stated with certainty except that the fungus infection was responsible for heavy losses; it could have been a primary or secondary cause. No similar condition had occurred in the previous 20 years of the project. Over-all evidence suggests that either an unusually pathogenic strain of fungus was involved or that circumstances resulted in an unusual combination of stresses that allowed it to get out of control and progress far beyond what would be expected from any previous experience. The lesson to be learned is that the confinement conditions necessary to maintain multiple genetic stocks for breeding and for selection based on continued exposure to a disease-producing agent can create unusual cultural hazards from other agents that may require unique precautions or corrective measures. At the very least, backup populations of the most-valued genetic stocks should be produced and maintained in a separate environment.

The impact of the fungus epizootic on plans for using the best selected strains was disastrous. The brook trout strains that were not completely eliminated were decimated to a point where procurement of eggs was impossible during the 1971 breeding season. The disease appeared to prevent normal development of sex products, especially in females. An unbalanced sex ratio was also observed in the brook trout strains. Survivors in the most drastically reduced lots consisted only of impotent females plus two or three males. Premium strains of brown trout, because of larger numbers prior to the epizootic and lesser over-all losses, did produce sufficient eggs to assure continuation of the strains.

DISCUSSION

This paper, together with the previous one (Ehlinger, 1964), indicate that, over the period from 1952 to 1972, a level of resistance to furunculosis was developed in both brook trout and brown trout by selective breeding and was demonstrated under controlled exposure conditions in the laboratory and in limited field tests. Variation in cultural environments makes it difficult to set exact limits on the degree of resistance attained. In the laboratory, a survival of 92 per cent was recorded for fingerlings of a resistant strain of brown trout after heavy exposure to the disease, compared with only 10 per cent in the control or unselected strain used. For brook trout, comparative resistance data were usually based on ST_{50} values as determined in controlled laboratory expo-

sure. In 1969, one test showed an ST_{50} value of 205.6 hours for a resistant strain of brook trout, compared with 114.3 hours for the control strain, with a difference of 28.7 hours being statistically significant.

Field testing of resistant strains was encouraging but not sufficiently complete to establish their economic worth. Some comparisons showed selected strains to perform as well on a cultural basis as existing hatchery stocks while convincingly exceeding them in resistance to furunculosis when natural epizootics occurred. Tested brook trout strains, while demonstrating a satisfactory level of resistance to furunculosis, were observed to be more susceptible to gill disease than native stock. On the basis of comparative performance, a furunculosis-resistant strain of brown trout was added at the State's largest brood stock hatchery.

Increasing resistance to furunculosis by mating individual pairs may have merit, but the technique proved impractical with the available facilities. Difficulties were encountered in maintaining the small lots of progeny as well as their parents. Progeny of the few individual matings that survived were not superior to those derived from the usual mass selection procedure. This method was not adequately tested, but it was obvious that to correct problems that arose and to supply the necessary inputs would require more facilities and funds than were available.

By the spring of 1971 it was apparent that resistance to furunculosis had leveled off with no dramatic or really significant increase over that of the established, best-performing strains having occurred for several years. It seemed clear that the readily attainable objectives of the project had already been reached. Nevertheless, it was felt that it would be desirable to continue the work to develop resistance to additional geographic strains of *A. salmonicida,* and plans were made to do this. However, after the fungus epizootic the following summer and fall, it was decided to terminate the project, although it was contemplated that some selective breeding and exposure to *A. salmonicida* of the premium strains of brook trout and brown trout on hand would be continued by hatchery personnel so that a reversion of resistance would not occur.

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TOXICITY OF DIQUAT AND CUTRINE TO FINGERLING BROWN TROUT

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ABSTRACT

The algicide Cutrine (7.1 per cent copper) and aquatic herbicide Diquat (35.3 per cent diquat dibromide) were tested to determine their toxicity to fingerling brown trout. When used alone, Cutrine had a 96-hour TL_m of 0.198 milligrams of copper per liter and Diquat had a 96-hour TL_m of 20.4 milligrams of diquat cation per liter. The data indicate that in combination the two chemicals acted synergistically. A concentration of 5.5 milligrams of diquat per liter killed only 5 per cent of the test fish after 96 hours, while a copper concentration of 0.162 milligrams per liter killed 30 per cent during the same length of time. When these two concentrations were combined there was no survival after 24 hours.

Aquatic weed problems in lakes and ponds may involve overabundant algae and higher aquatic plants. A chelated copper compound such as Cutrine (Applied Biochemists, Inc. has been found to be effective for controlling algae in both hard and soft water, and the chemical Diquat (Chevron Chemical Co. is effective for killing higher aquatic plants. When chemical treatment is the desired means of control, joint use of these two chemicals would appear to be advantageous. However, little work has been done on the effects of this combination on fish and other aquatic life, although Hiltibran (1972) reported that it was very effective in controlling some aquatic plant species.

Copper, most frequently in the sulfate form, has been used for many years to control algae, and numerous researchers have studied its effects on aquatic life (Hale, 1946; Mount and Stephan, 1969; Doudoroff and Katz, 1953). From these studies it is clear that copper is highly toxic to fishlife even in relatively low concentrations. Diquat, on the other hand, has a relatively low level of toxicity to fish. Several researchers (Gilderhus, 1967; Cope, 1966; Surber and Pickering, 1962 found that concentrations which kill fish are considerably greater than those necessary to kill susceptible plants.

The toxicity to fish of a Diquat and Cutrine combination has received little attention. May et al. (1973) studied the effects of Diquat plus copper sulfate on aquatic invertebrates and in field situations observed a significant decline in the number of such invertebrates following treatment. A brief study conducted by the Florida Department of Natural Resources implied that the combination is relatively safe to fish (Anonymous, 1972).

The present study was undertaken to determine the toxicity of both Diquat and Cutrine to fingerling brown trout (*Salmo trutta*) and then to determine the toxicity of various combinations of the two chemicals. The results would indicate whether the toxicities of the two are strictly additive, less than additive (antagonistic) or more than additive (synergistic).

PROCEDURE

The studies were conducted in laboratory facilities at the Rome State Fish Hatchery. The brown trout fingerlings tested were obtained from that hatchery and averaged 40.3 millimeters in length. Static bioassay procedures were used in preference to a continuous flow-through technique because it was felt that they more closely approximated the natural situation in a lake or pond, where a chemical is applied once and gradually breaks down before being flushed from the system. The methods described by Doudoroff et al. (1951) were followed using 20-liter glass jars filled to a volume of 16 liters and placed in a constant-temperature water bath. The tests were allowed to run for 96 hours. Rome Hatchery spring water was used throughout the study. The initial dissolved oxygen was 11.2 milligrams per liter and did not fall below 5.6 milligrams per liter during any of the tests. Methyl orange alkalinity was 100 milligrams per liter, pH was 7.5 and the temperature for all of the bioassay tests was held at 18.3° C. (65° F.). Complete water chemistry data for the hatchery spring water were given by Burdick et al. (1954).

The test fish were acclimatized for at least 7 days prior to being used for bioassay work, and they were unfed for 3 days prior to use. Mortality in these fish was less than 10 per cent throughout the study. Five fish were placed in each of the test jars, and a total of 20 fish were exposed to each of the test concentrations. Mortality and dissolved oxygen levels were recorded at 24, 48 and 96 hours.

The concentrations of Cutrine were expressed as milligrams per liter of copper, based on a formulation of 0.76 pounds of copper per gallon. Concentrations of Diquat were likewise calculated on the basis of diquat cation, using a 2 pounds per gallon formulation.

After the toxicities of Cutrine and Diquat were determined independently, a bioassay using equal volumes of each chemical was set up. This was done because one possible application procedure would be to calculate the amount of Diquat needed, reduce the amount by half and add an equal amount of Cutrine. Tests using a constant concentration of Cutrine and varying the concentrations of Diquat were also run.

RESULTS

Cutrine was found to be relatively fast acting in its toxicity to brown trout (Table 1 and Figure 1). The 24-hour median tolerance limit

TABLE 1. SURVIVAL OF FINGERLING BROWN TROUT EXPOSED TO VARIOUS CONCENTRATIONS OF CUTRINE AT 18.3° C. (65° F.)

Concentration		Size of test fish* (millimeters)	Survival (per cent)		
Copper (milligrams per liter)	Cutrine (microliters per liter)		24 hours	48 hours	96 hours
§	§	43.9	100	100	100
0.029	0.32	43.2	100	100	95
0.090	1.0	43.0	100	100	95
0.162	1.8	43.8	75	75	70
0.289	3.2	43.9	15	10	10
0.902	10.0	47.1	0	0	0

* Average of 20 fish.

§ Control group.

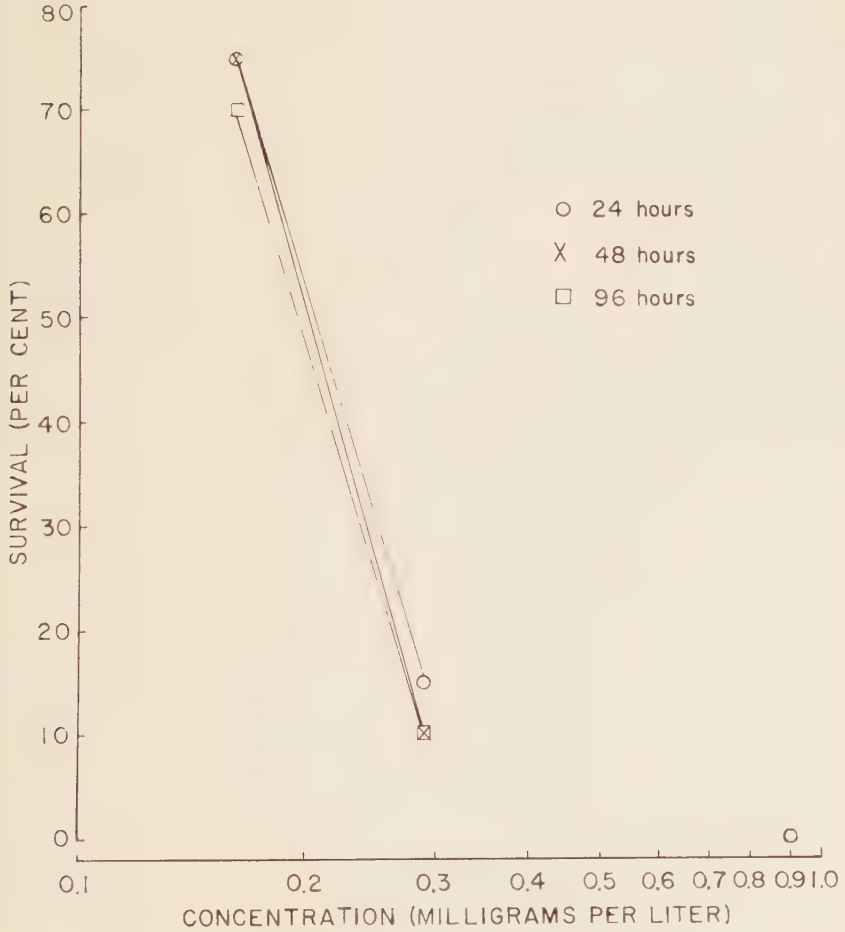

Figure 1. Relationship of survival to concentration for fingerling brown trout exposed to Cutrine for three time periods.

Table 2. Survival of Fingerling Brown Trout Exposed to Various Concentrations of Diquat at 18.3° C. (65° F.)

Concentration		Size of test fish* (millimeters)	Survival (per cent)		
Diquat (milligrams per liter)	Diquat (microliters per liter)		24 hours	48 hours	96 hours
§	§	37.0	100	100	100
5.54	23.1	37.2	100	100	95
17.5	73.1	37.1	85	75	70
23.1	96.3	37.1	70	40	30
30.7	128	35.6	65	25	5
55.0	229	37.4	15	0	0
176	733	38.2	5	0	0

* Average of 20 fish.

§ Control group.

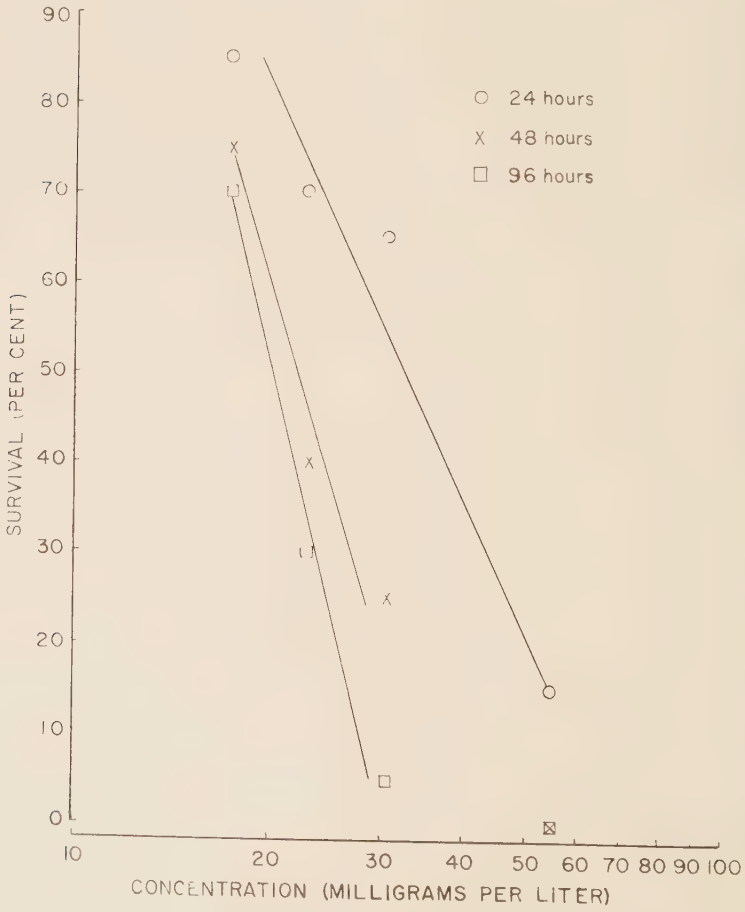

Figure 2. Relationship of survival to concentration for fingerling brown trout exposed to Diquat for three time periods.

Table 3. Survival of Fingerling Brown Trout Exposed to Equal Concentrations (by volume) of Cutrine and Diquat at 18.3° C. (65° F.)

Concentration			Size of test fish* (millimeters)	Survival (per cent)		
Copper§	Diquat§	Cutrine and Diquat†		24 hours	48 hours	96 hours
§§	§§	§§	40.8	100	100	95
0.090	0.24	1.0	38.1	100	100	95
0.162	0.43	1.8	39.8	70	60	55
0.216	0.58	2.4	38.8	15	5	5
0.325	0.86	3.6	40.4	5	5	0

* Average of 20 fish.
§ Milligrams per liter.
† Microliters per liter of each.
§§ Control group.

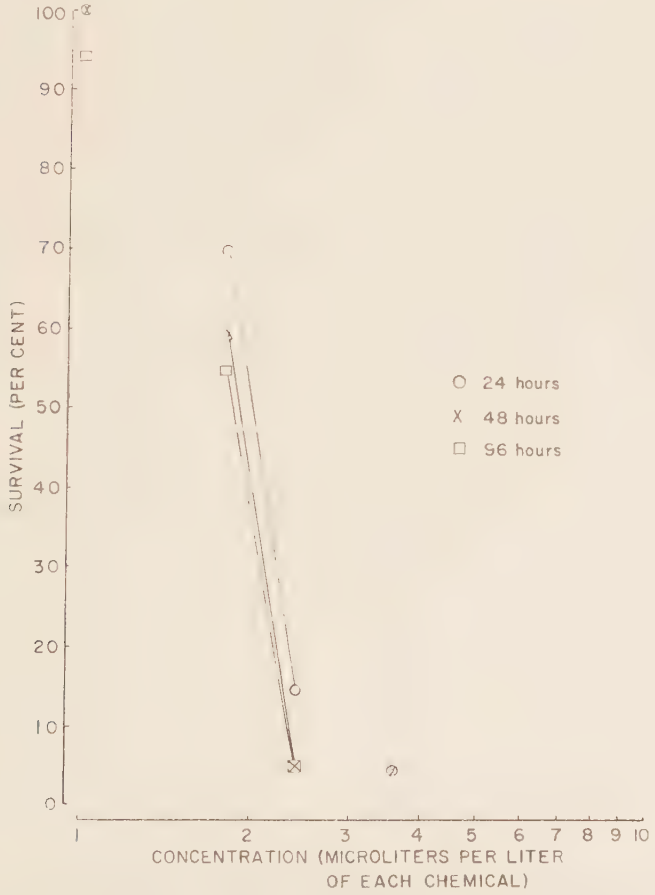

Figure 3. Relationship of survival to concentration for fingerling brown trout exposed to equal concentrations (by volume) of Cutrine and Diquat for three time periods.

TABLE 4. SURVIVAL OF FINGERLING BROWN TROUT EXPOSED TO A COMBINATION OF 1.8 MICROLITERS OF CUTRINE PER LITER AND VARIOUS CONCENTRATIONS OF DIQUAT AT 18.3° C. (65° F.)

Concentration				Size of test fish* (millimeters)	Survival (per cent)		
Copper§	Cutrine†	Diquat§	Diquat†		24 hours	48 hours	96 hours
§§	§§	§§	§§	40.5	100	95	95
0.162	1.8	0.0	0.0	43.8	75	75	70
0.162	1.8	0.43	1.8	39.8	70	60	55
0.162	1.8	1.3	5.5	40.6	60	50	50
0.162	1.8	2.3	9.6	43.3	35	30	30
0.162	1.8	4.1	17.2	40.1	10	5	5
0.162	1.8	5.5	22.9	40.3	0	0	0

* Average of 20 fish.
§ Milligrams per liter.
† Microliters per liter.
§§ Control group.

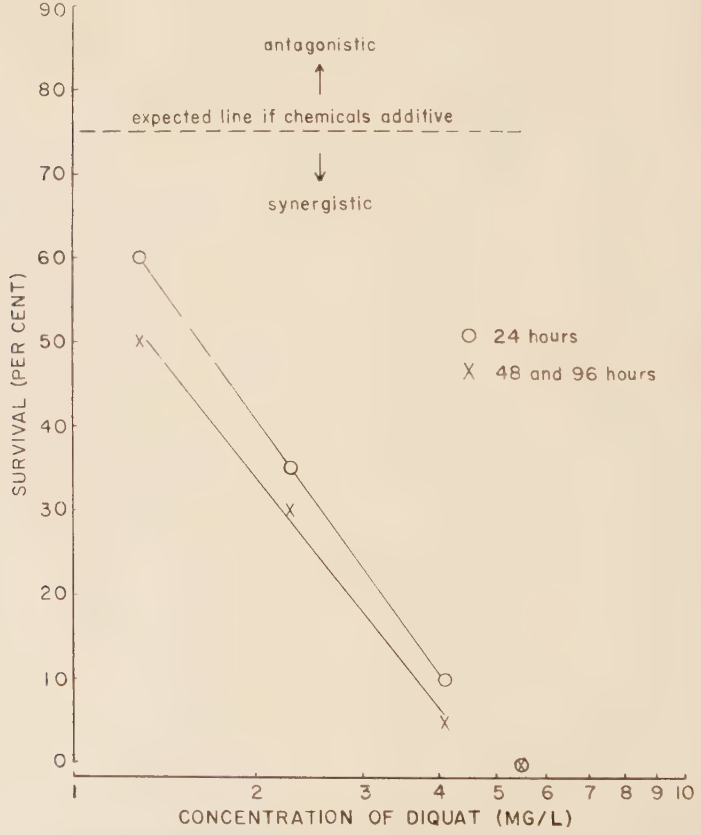

Figure 4. Relationship of survival to concentration for fingerling brown trout exposed to various concentrations of Diquat in addition to 0.162 milligram of copper per liter for three time periods. The position of the data points below the additive line indicates that the action of the two chemicals was synergistic.

(TL_m) of 0.207 milligram of copper per liter of solution was fairly close to the 96-hour TL_m of 0.198 mg. copper per liter. It is evident that at 18.3° C. (65° F.) most of the mortality due to Cutrine occurred within the first 24 hours following exposure.

Diquat was found to be slower acting than Cutrine, but it created fish mortality over a longer period of time (Table 2 and Figure 2). The 24-, 48- and 96-hour TL_m's for Diquat were, respectively, 32.6, 22.4 and 20.4 milligrams diquat cation per liter.

When Diquat and Cutrine were mixed in equal volumes, the toxicity was found to be slightly greater than that of Cutrine alone (Table 3). This seemed to indicate that the Diquat was causing some of the mortality, even though when Diquat alone was tested at these low concentrations, no mortality was observed. Figure 3 shows the 24-, 48- and 96-hour TL_m's of the combination to have been, respectively, 2.12 μl. per liter (0.191 mg. copper per liter, 0.51 mg. diquat per liter); 2.05 μl. per liter (0.185 mg. copper per liter, 0.49 mg. diquat per liter); and 1.85 μl. per liter (0.167 mg. copper per liter, 0.44 mg. diquat per liter) of each chemical.

A concentration of 0.162 mg. copper per liter was found to kill 25 per cent of the test fish in 24 and 48 hours and 30 per cent in 96 hours (Table 1). Also, the data indicated that a concentration of less than 5.5 mg. diquat per liter, when used alone, would cause negligible mortality (Figure 2). However, when concentrations of Diquat in this range were tested in combination with 0.162 mg. copper per liter, definite increases in mortality occurred (Table 4 and Figure 4). A diquat concentration of 1.3 mg. per liter combined with 0.162 mg. copper per liter killed 50 per cent of the test fish after 48 or 96 hours.

Figure 4 shows graphically the results of this bioassay and indicates the synergistic action of Cutrine and Diquat in combination. Had the toxicities of the two chemicals been strictly additive, the proportion of the fish surviving after 24 or 48 hours would have been 75 per cent for all the concentrations tested.

Table 5. Median Tolerance Limits For Fingerling Brown Trout Exposed to Cutrine, Diquat and Two Combinations of These Toxicants at 18.3° C. (65° F.)

Toxicant	Median tolerance limit (TL_m)*		
	24-hour	48-hour	96-hour
Cutrine	0.207	0.203	0.198
Diquat	32.6	22.4	20.4
Diquat and Cutrine (equal volumes)	0.51 : 0.191	0.49 : 0.185	0.44 : 0.167
Diquat and 0.162 milligram of copper per liter	1.63	1.34	1.34

* Milligrams per liter active ingredient.

The median tolerance limits for Cutrine, Diquat and various combinations of the two are summarized in Table 5.

DISCUSSION

The data indicate that Cutrine is quite toxic to brown trout and that in combination with Diquat it is primarily the Cutrine which causes the mortality. It has been known for some time that copper is more toxic to trout than to other fish species (Hale, 1946). In agreement with this, tests by the authors have shown that trout are more susceptible to Cutrine than are largemouth bass (unpublished data). Consequently, it is often considered unwise to apply copper sulfate in waters inhabited by trout.

Diquat was found to be relatively safe to brown trout, with toxic concentrations being well above those necessary to kill aquatic vegetation. For rainbow trout, Gilderhus (1967) found a 96-hour TL_m of 11.2 ppm diquat and Cope (1966) reported a 48-hour TL_m of 20.0 ppm diquat. Present findings showed Diquat to be slightly less toxic to brown trout.

Assuming an average water depth of 3 feet, an application of 1 gallon of Diquat plus 1 gallon of Cutrine per acre would create concentrations of 0.245 mg. diquat cation and 0.093 mg. copper per liter. Although these levels are below the calculated TL_m, and higher concentrations were necessary to cause mortality (Table 3), they include no margin of safety. If this amount of chemical were applied over areas where the water was only 1 foot deep, then the resulting concentrations would be 0.735 mg. diquat and 0.28 mg. copper per liter. Such concentrations could result in some fish mortality. A safer application rate for Cutrine and Diquat in combination might be possible if the amount of Cutrine needed could be reduced considerably. Whether or not a rate of 0.9 gallon of Diquat and 0.1 gallon of Cutrine per acre would effectively control aquatic vegetation would have to be tested.

The present study dealt with toxic effects on brown trout. Whether or not other species of fish would respond similarly would depend upon their susceptibility to both Diquat and Cutrine. Many ponds and lakes that are treated for overabundant aquatic vegetation contain mainly warm-water fishes. The response of such species to a Diquat-Cutrine combination, as well as the various effects on aquatic insects and zooplankton, will require additional research.

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CRUSTACEAN ZOOPLANKTON POPULATIONS AND CONCURRENT SURVIVAL OF LARVAL YELLOW PERCH IN ONEIDA LAKE[1]

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ABSTRACT

Density of copepod nauplii, the primary food of larval yellow perch, was lowest in two years of good larval survival and highest in the year with poorest survival. Positive correlations between catches of larval perch and napulii in years of high perch density, however, suggest that nauplii populations were not depleted by predation by yellow perch. Dependence of zooplankton populations on environmental factors that directly influence the survival of perch eggs and larvae probably accounts for the close correlation between perch survival and the densities of several minor food organisms, e.g., *Bosmina* and calanoid copepods.

Density of food organisms may be important to the survival of larval fish, especially during the critical transition from endogenous to exogenous sources of nutrition (Braum, 1967). Clarification of factors affecting the survival of larval yellow perch (*Perca flavescens*) in Oneida Lake is particularly critical since the perch is the predominant forage species. The strength of a given year class determines the degree of cannabalism among walleyes (*Stizostedion vitreum*), the primary sport fish, and the intensity of predation by the walleye on yellow perch and other forage species during that year (Forney, 1971, 1974). This paper examines the relation between populations of food organisms and the survival of perch larvae.

STUDY AREA AND METHODS

Oneida Lake has a surface area of 207 square kilometers, a mean depth of 6.8 meters and a maximum depth of 16.8 meters. It has only one distinct bay. Although yellow perch spawning is concentrated in the northeastern portion of the lake, newly-hatched larvae are rapidly dispersed by wind-driven surface currents so that large numbers occur throughout the lake during the time eggs are hatching in May (Forney and Noble, 1970).

The abundance and composition of zooplankton and the density of yellow perch larvae were measured at 20 inshore sites over known spawning grounds (Figure 1) during the period perch were hatching from 1970 to 1974. Collections were made during a 1- to 3-day interval with a Clarke-Bumpus sampler towed in a circular pattern at depths of 0.3, 0.6, 0.9, 1.2 and 1.5 meters for 30 seconds in 1970, 1971, 1973 and 1974 and for 15 seconds in 1972. The sampler was equipped with a flowmeter

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-17-R. John Forney reviewed the manuscript.

Figure 1. Map of Oneida Lake showing sites (solid circles) where zooplankton and yellow perch larvae were collected in 1970-1974.

and #20 net (80μ aperature), except that in 1972 a #10 net (158μ aperature) was also used at 10 sites where the #20 net appeared clogged with rotifers. For each site, the number of each organism per liter was estimated from counts made of three 1-milliliter aliquots of the total sample. For statistical purposes, catches of larvae per standard meter count (catch +1 in years when some catches were zero) and of copepod nauplii per liter strained were converted to logarithms to reduce variation in density and to normalize the distributions. In addition, the lengths of 30 copepod nauplii from each site were measured to the nearest 0.01 millimeter with an ocular micrometer.

The stomachs of 378 perch larvae (mean total length = 7.4 millimeters) captured in the tows in 1972 and 1973 were examined for food. The species and numbers of zooplankton present were recorded. Lengths of copepod nauplii in the stomachs were also measured to the nearest 0.01 millimeter.

The survival of yellow perch during its early life stages from 1970 to 1974, based on estimates of eggs spawned and the number of surviving postlarvae, were taken form Table 3 of Clady (1976). Egg production was determined from mark-and-recapture estimates of adult stock and measurements of fecundity. The abundance of the resulting cohort was determined by annual surveys of the larvae.

RESULTS

Copepod nauplii were found in 55 per cent of the fish containing food and numerically were the most important food item in the stomachs of prolarvae collected in 1972 and 1973 (Table 1). Cyclopoid and calanoid copepods and early instar *Bosmina* were present in smaller proportions (39, 25 and 11 per cent, respectively).

At the 10 sites where zooplankton was captured with both #10 and #20 mesh nets in 1972, the catches of *Cyclops, Diaptomus* and *Daphnia*

Table 1. Relative Occurrence of Major Foods of Yellow Perch Larvae in Oneida Lake in 1972 and 1973

Item	1972	1973	Total
	Yellow perch larvae*		
Number	354	24	378
Number with food	120	4	124
	Major foods		
Copepod nauplii			
Number	102	2	104
Occurrence (per cent)	55	50	55
Cyclopoids			
Number	68	4	72
Occurrence (per cent)	38	50	39
Calanoids			
Number	25	0	25
Occurrence (per cent)	16	0	15
Bosmina			
Number	22	0	22
Occurrence (per cent)	12	0	11

* Range in length: 6.0 - 11.3 millimeters.

by the two sizes were not significantly different, but greater numbers of *Bosmina* and *Chydorus* were taken in the #10 mesh ($t=2.40$ and 3.56, respectively; $P=0.05$), while the catch of copepod nauplii per liter was significantly greater in the #20 mesh ($t=4.80$). In both cases where the differences were significant, the catch in the most efficient net was used.

The density of copepod nauplii was low in 1970 and 1971 when survival of perch from the egg to the postlarval stage was high, and nauplii density was highest in 1973 when perch survival was lowest (Table 2). The larger size of copepod nauplii in 1970 and 1971 could have obscured a relationship between nauplii density and perch survival if the vulnerability of nauplii to capture were a function of size. However, there was no evidence that perch larvae consistently selected either large or small nauplii (Table 3).

The frequencies of copepod nauplii and yellow perch larvae recorded each year at the 20 sites in Oneida Lake are given in Table 4. Correlation coefficients between logarithms for the densities of perch and nauplii were positive in 1970 (0.74) and 1971 (0.13) when perch density was high, and they were negative in 1972 (−0.15) and 1973 (−0.45) when perch density was lower. (Samples from 1974 were discarded before perch larvae were enumerated.)

Annual variation in the densities of other zooplankters was evident (Table 2), but their relation to perch survival is obscure since they were

Table 2. Survival of Young Yellow Perch in Relation to Their Food Supply in Oneida Lake, 1970-1974

Year	Date	Survival* (per cent)	Number of zooplankters (per liter)§								Mean length of nauplii† (millimeters)
			Bosmina	*Chydorus*	*Daphnia*	*Cyclops*	*Diaptomus*	*Epischura*	*Mesocyclops*	Copepod nauplii	
1970	May 19-21	9.0	0.8	0.0	59.1	22.1	34.2	2.0	0.2	14.5	0.25
1971	May 30	8.4	2.7	0.0	33.5	4.5	21.0	1.3	t	10.7	0.24
1972	May 27	7.7	6.8	4.5	1.6	9.2	5.9	0.4	0.2	17.5	0.23
1973	May 12-13	1.6	0.1	0.0	27.7	44.9	0.0	16.0	0.0	25.0	0.23
1974	May 19	2.8	t	0.2	50.7	10.1	t	19.9	0.3	17.3	0.18

* From Table 3 of Clady (1976).

§ "t" = trace.

† For sample of 600.

Table 3. Size of Copepod Nauplii in Stomachs of Yellow Perch Larvae Compared With That of Source Population For Various Sites in Oneida Lake, May 27, 1972

Site	Larvae examined*		Nauplii recorded			
			In sample		In source population	
	Number	Mean length (millimeters)	Number	Mean length (millimeters)	Number	Mean length (millimeters)
South Bay	1	6.4	3	0.24	30	0.22
3-Mile	36	7.5	48	0.20	30	0.21
Bullhead	1	9.0	1	0.20	30	0.21
Sunset	7	7.4	12	0.23	30	0.21
Taft	1	6.5	1	0.20	30	0.22
Bernhards E	3	9.3	4	0.23	30	0.22
Potter	3	9.9	4	0.29	30	0.25
Colon	2	9.8	8	0.27	30	0.24
Eaton	2	9.0	2	0.20	30	0.24
Jewel	1	7.4	1	0.25	30	0.25
North Bay	4	9.2	17	0.25	30	0.21
Total	61	8.6	101	0.22	330	0.22

* Range in length: 6.1 - 10.9 millimeters.

Table 4. Number of Copepod Nauplii and Yellow Perch Larvae Captured At 20 Sites in Oneida Lake, 1970-1974

Site	Copepod nauplii (number per liter)					Yellow perch larvae (number per standard count)			
	1970	1971	1972	1973	1974	1970	1971	1972	1973
South Bay	4.3	15.2	4.4	26.7	19.2	61.7	645	0	3.3
Lewis Point	10.2	17.5	7.4	48.6	20.3	48.6	274	0.9	1.8
Lakeport	9.1	10.0	5.5	38.0	6.8	26.8	1,178	1.5	1.2
Delmarter	14.0	6.5	28.3	66.5	27.6	46.2	1,083	0	2.3
Billington	3.8	7.2	24.9	30.4	14.9	18.4	78	0	2.4
Fisher	2.1	9.0	12.4	89.5	14.3	3.5	301	0	2.2
Maple	2.2	2.6	2.9	24.8	14.3	35.1	112	0	0
Lower South	2.3	6.2	50.8	13.8	7.3	0.9	56	0	5.3
3-Mile	17.6	2.5	3.6	2.5	6.7	103.0	581	229.0	6.4
Bullhead	12.1	11.7	7.5	11.8	18.2	25.1	582	38.9	31.8
Sunset	18.2	4.8	9.7	4.3	12.0	0	1,513	43.5	8.3
Dakin	18.0	5.2	18.4	7.0	23.2	309.0	1,104	4.7	4.7
Taft	26.1	3.4	19.6	6.0	17.7	144.0	2,156	11.1	22.3
Bernhards W	13.6	14.4	26.5	5.5	23.4	175.0	709	6.3	7.5
Bernhards E	17.2	9.4	16.1	2.3	13.0	84.1	638	9.7	4.4
Potter	43.3	8.7	20.3	9.6	31.3	220.0	1,688	5.4	2.9
Colon	26.1	9.7	10.9	15.5	13.1	146.0	1,625	4.9	10.0
Eaton	18.5	54.0	20.5	25.2	41.8	139.0	1,036	7.3	9.9
Jewel	19.4	10.5	18.4	31.8	8.8	195.0	1,046	1.6	11.1
North Bay	11.3	5.3	42.7	39.4	12.6	44.0	683	21.8	2.3

consumed by the larvae to only a minor degree. The densities of *Bosmina* and *Diaptomus* were greater in years of high perch survival (1970-1972), while that of *Epischura* was high in years of poor perch survival (1973 and 1974).

DISCUSSION

Two deficiencies exist in this study which make interpretation of the results difficult. One is that rotifers, which are an important food of perch larvae in some lakes (Siefert, 1972), were not captured in representative numbers by the #20 mesh net. Although rotifers were found in only three perch stomachs, failure to estimate their abundance could have contributed to the lack of evidence of a strong relationship between food density and concurrent survival if their actual importance as food were much greater. The other deficiency is that the food eaten by yellow perch larvae was not determined as precisely in the year of relatively poor survival (1973; only four larvae with food) as it was in the year of relatively good survival (1972). Greatly different reliance on rotifers, *Bosmina* or calanoid copepods for food in 1973 and 1974, as suggested by the greater occurrence of calanoids in the limited data for 1973 (Table 1), could possibly clarify predator-prey relationships.

Nevertheless, the importance of copepod nauplii as an initial food of perch in Oneida Lake is consistent with observations in other eutrophic lakes (Siefert, 1972). Predation by perch on nauplii could have contributed to differences in the density of nauplii since perch were more abundant in 1970 and 1971 than from 1972 to 1974. Cushing (1973) presented evidence that high densities of marine fish larvae may deplete populations of food organisms in nursery areas.

A negative relation between the densities of perch larvae and copepod nauplii would be anticipated if the larvae depleted the supply of nauplii over spawning grounds in Oneida Lake. However, the positive correlations between catches of larvae and nauplii for years of high perch density do not support the assumption that predation by perch controlled nauplii density. The correlations do suggest that differences in the distribution of nauplii may have increased their availability to perch in 1970 and 1971 compared with 1972 and 1973, and that these differences in distribution could have compensated for differences in the mean density of nauplii during the 4-year period. However, the distribution of larvae and zooplankton in bays changes rapidly (Houde, 1969), and relationships between food organisms and larval perch must be viewed with caution since food consumption cannot be related to the production of food.

The importance of food abundance in regulating the survival of larval fish in lakes has been frequently stressed but seldom demonstrated because interactions between prey species, starvation, growth rate and predation are all a function of the food supply and environmental conditions, particularly temperature. Variation in food abundance could accentuate differences in survival if zooplankton populations were regulated by climatic factors such as temperature and wind which have been

shown to directly influence survival of perch eggs and larvae in Oneida Lake (Clady, 1976). Such causal relationships are suggested by the strong correlations between perch survival and the abundance of several minor food organisms, e.g., *Bosmina, Diaptomus* and *Epischura.*

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SEASONAL MIGRATION OF STRIPED BASS IN LONG ISLAND SOUND[1]

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ABSTRACT

Returns from a program of tagging striped bass conducted by the American Littoral Society between 1966 and 1972 are reviewed with particular attention to population movement within Long Island Sound. The data indicate that bass enter the Sound from both ends but chiefly from the east and that there is a stable summer population with the fall migration being one of primary egress through the eastern passages. Most significant is evidence of an intra-Sound fall migration as bass along the entire Connecticut coast appear to migrate to the central part of the Sound, cross to the Long Island shore and then migrate out via the eastern end of the Sound.

Despite intensive tagging studies conducted over the past three decades and directed toward an understanding of the origin, migration and segregation of striped bass (*Morone saxatilis*) in the western Atlantic, there is still controversy as to their origin and segregation. The basic inferences from the comprehensive study by Merriman (1941), and later reinforced by Alperin (1966), Clark (1968) and Stolte (1973), are: (1) there is a migration along the Atlantic Coast to the north in the spring and to the south in fall; (2) the summer population in northern waters is relatively stationary; (3) the most intense migrations take place in the waters between Massachusetts and Virginia; (4) there is no apparent coastal migration of stripers less than 2 years old; (5) there is very small contribution of striped bass from North Carolina to the fishery in northern waters. Also, it has been generally believed that Chesapeake Bay and its tributary system is the major spawning and nursery area for striped bass found along the Atlantic Coast north of Chesapeake Bay, and that a separate race (based on meristic characters) inhabits the Hudson River-New York City area (from Jones Beach west) and contributes only a small percentage to the migrating coastal population (Porter and Saila, 1969).

[1] Contribution No. 68 of the New York Ocean Science Laboratory. The authors wish to acknowledge the American Littoral Society for their help and encouragement. The maps were prepared by David Gould. The manuscript was reviewed by Richard Schaefer and Clarence Hickey, whose comments are appreciated. The work was supported by funds to the New York Ocean Science Laboratory from the State of New York (BR-73-18) and the Long Island Lighting Company.

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Relatively little work has been done, however, concerning the activities of striped bass within Long Island Sound. Past studies, as summarized by Clark (1968), have concluded that successful spawning is not to be expected in the tributaries of Long Island Sound, and Clark suggested that the Hudson River may be the main source of migrants to the Sound although most previous researchers had opted for the Chesapeake area. But Clark also stated that different "contingents" of bass occupy the Sound at different times of year. Merriman (1941) believed that spring migrations apparently take stripers from the tip of Long Island straight across open water to the shores of Rhode Island and Connecticut and that fall migrations bring them back directly to Montauk with a minimum of shoreline travel.

The present study was undertaken to determine the winter and summer grounds of striped bass that are taken in the Long Island Sound fishery, using data for tagged fish that were later recovered. All the returns analyzed had been tabulated in the Quarterly Bulletin of the American Littoral Society (*Underwater Naturalist*). All tagging was done between 1966 and 1972 by members of the Society under the supervision of Graham MacMillan, director of its tagging program.

A drawback to this type of program is that returns are biased by (1) the geographic clustering the Society membership, (2) the geographic intensity of tagging efforts by particular members, (3) the predominantly selective release of "short" bass, and (4) the fact that commercial catches cannot be screened as closely as the sport catch. The analyses then carry a bias because of a greater number of tagged fish being released in one contingent than another (e.g., there was little tagging effort in the Chesapeake and North Carolina areas) and because of tagged fish being caught but not noticed until they reached the market (e.g., there were returns from the Fulton Fish Market in New York City).

Only tagged fish that had been recovered within three seasons (e.g., tagged during the summer and recovered by the following spring) were considered, since fish at large for a year or more might have made several migrations to possibly different areas. The seasons recognized, based on Long Island Sound's oceanographic conditions, were: winter (January, February and March); spring (April, May and June); summer July, August and September); fall (October, November and December).

For purposes of the study, the Sound was divided into six areas. Area I included the waters off eastern Long Island from Roanoke Point to Fishers Island; Area II, off central Long Island from Eaton's Neck to Baiting Hollow; Area III, off western Long Island from Kings Point to Northport Bay; Area IV, off eastern Connecticut from Guilford to Stonington; Area V, off central Connecticut from Stamford to Branford; Area VI, off the western part of the north shore from Eastchester Bay

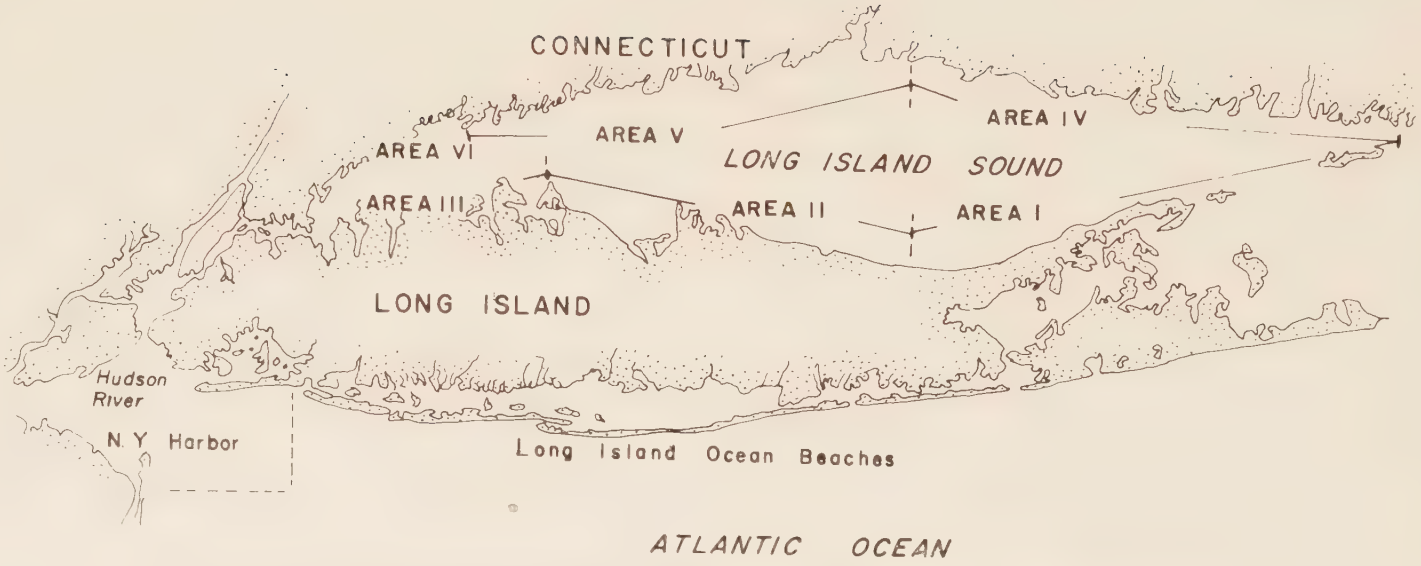


Figure 1. Areas in Long Island Sound used in recording release and recovery data for tagged striped bass.

(N.Y.) to Greenwich (Conn.). The relative locations of these areas are shown in Figure 1.

RECOVERIES BY AREA

A total of 581 returns were analyzed, of which 231 were fish that had been tagged in the Sound but recovered outside it. Of the remaining 350 (60 per cent) that were recovered in the Sound, 306 (87 per cent) had also been tagged there and 44 (13 per cent) had been tagged in outside areas. In accordance with the pattern of Clark (1968), the data for both releases and recoveries were considered by area.

Area I

The greatest number of recoveries were made in this area, constituting the southeastern part of Long Island Sound from Roanoke Point to Fishers Island. Of the 108 tagged bass recovered from this area, 88 had been released inside the Sound and 20 outside.

Of the 88 released in the Sound and recovered in Area I, 14 had been released in that area and most of them were recovered during the summer. A significant proportion (62 per cent) were fish that had been released during the spring or summer, primarily in Area V or Area III, and recovered the following fall.

Recoveries of fish that had been tagged and released outside the Sound comprised 10 from Rhode Island, five from Maine and five from the Hudson River-New York City area. Of these, 71 per cent were recovered in the fall and were mostly fish that had been released during the spring and summer in Rhode Island waters and northward.

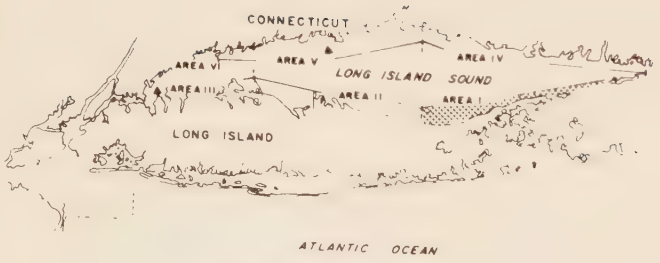
There were 26 returns from fish tagged in Area I. Of these, 14 came from within the same area, mostly during the summer of the year they were tagged, and three came from elsewhere in the Sound (Figure 2). Nine returns came from outside the Sound: four from the ocean side of eastern Long Island; four from New Jersey or southward; and one from Rhode Island. All of the returns from the ocean side of Long Island, New Jersey and southward represented fish that had been released during the spring or fall and recovered during the fall or winter.

Area II

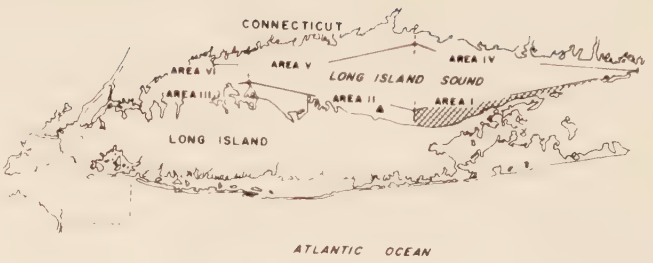
There were 36 recoveries in the area between Eaton's Neck and Baiting Hollow, all of which were fish that had been tagged within the Sound. Half were fall returns for fish tagged during the summer in Area V.

The 82 returns for fish tagged in Area II were evenly distributed between the Sound and waters outside it. Returns from within the Sound showed that fish tagged in Area II tended to remain there during the summer, although 77 per cent of the recoveries during the fall and

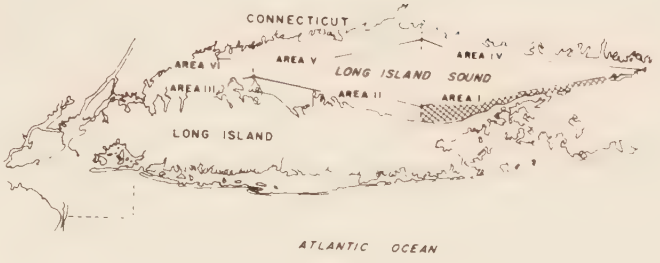
RELEASE AREA I



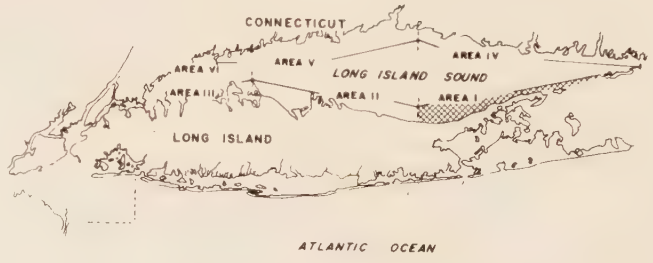
SPRING RETURNS



SUMMER RETURNS



NO FALL RETURNS



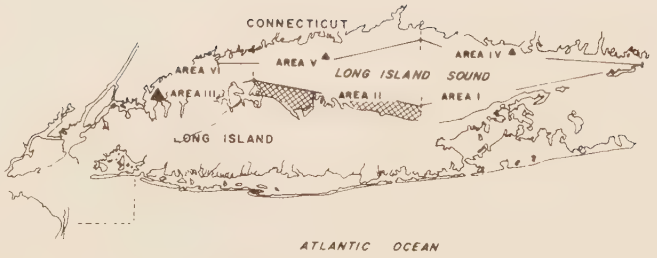
NO WINTER RETURNS

KEY

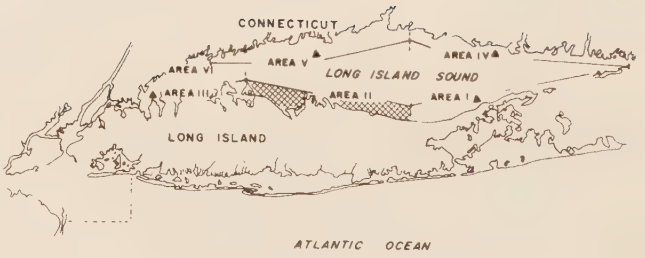
▲ LESS THAN 5 RETURNS
▲ 5–20 RETURNS
▲ MORE THAN 20 RETURNS

Figure 2. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area I.

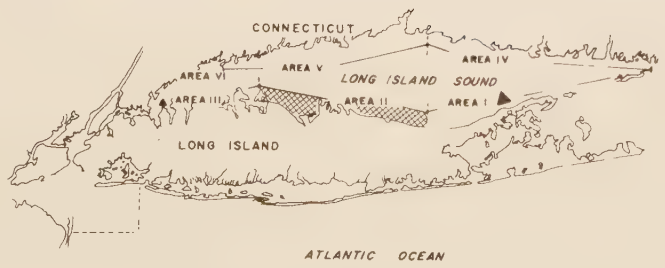
RELEASE AREA II



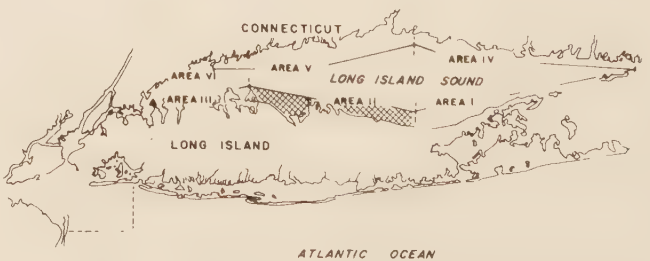
SPRING RETURNS



SUMMER RETURNS



FALL RETURNS



WINTER RETURNS

KEY

▲ LESS THAN 5 RETURNS
▲ 5-20 RETURNS
▲ MORE THAN 20 RETURNS

Figure 3. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area II.

winter came from Area I to the eastward (Figure 3). It is significant that there were only five returns from the Connecticut shore, of which only two were from the heavily fished Area V.

Of the returns from outside the Sound, 19 were from the Chesapeake Bay region, 15 from the ocean side of Long Island, two each from the Hudson River, New Jersey and Massachusetts, and one from Rhode Island. Of the Chesapeake returns, 15 per cent represented fish that had been released during the spring or summer and recovered in the fall, while for 78 per cent the corresponding interval was summer or fall to winter or spring. For the returns from the ocean side of Long Island, 60 per cent represented a release to recovery interval of summer or fall to fall, 20 per cent an interval of spring to summer, and 20 per cent an interval of spring to fall. All the fish recovered north of the Sound had been released during the spring and recovered during the late summer or fall.

Area III

A total of 37 recoveries were made off the western part of Long Island from Kings Point to Northport Bay, 43 per cent of which had also been released in Area III. The main outside contributor was neighboring Area II to the east with 11, while five came Area V and one from Area I at the eastern end of the Island. Four fish tagged outside the Sound, i.e., two in the Hudson River-New York City area, one in New Jersey waters and one on the ocean side of Long Island east of Jones Beach, were also recovered in this area.

There were 61 returns for fish tagged in Area III (Figure 4). Of these, 22 per cent were recovered within this area, while 20 per cent came from Area I, 18 per cent from the ocean side of Long Island, 13 per cent from New England, 13 per cent from the Chesapeake region and 11 per cent from Connecticut. Most of the returns from Area I and the ocean side of Long Island represented fish that had been released during the spring or summer and recovered during the fall, while for those from the Chesapeake region the corresponding interval was summer or fall to winter or spring.

Area IV

In these waters at the eastern end of the Connecticut shore between Guilford and Stonington there were a total of 28 recoveries, nine of which had also been released in Area IV. Of those released elsewhere, nine came from Area V, three from Area II, two from Area III and five from outside the Sound. Of the latter, two came from the Hudson River-New York City area and one each from New Jersey, Rhode Island and Massachusetts. A large proportion of the recoveries (46 per cent)

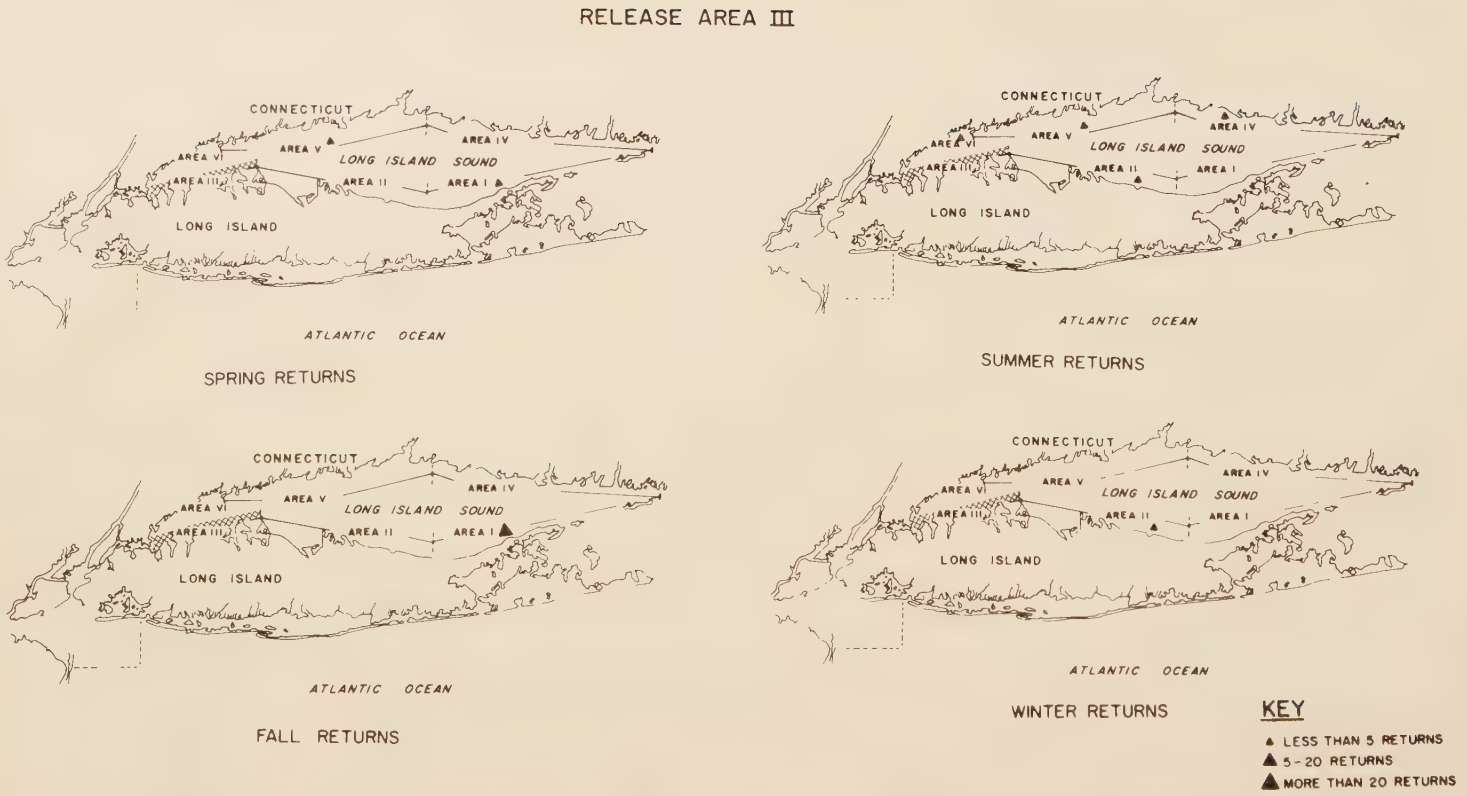


Figure 4. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area III.

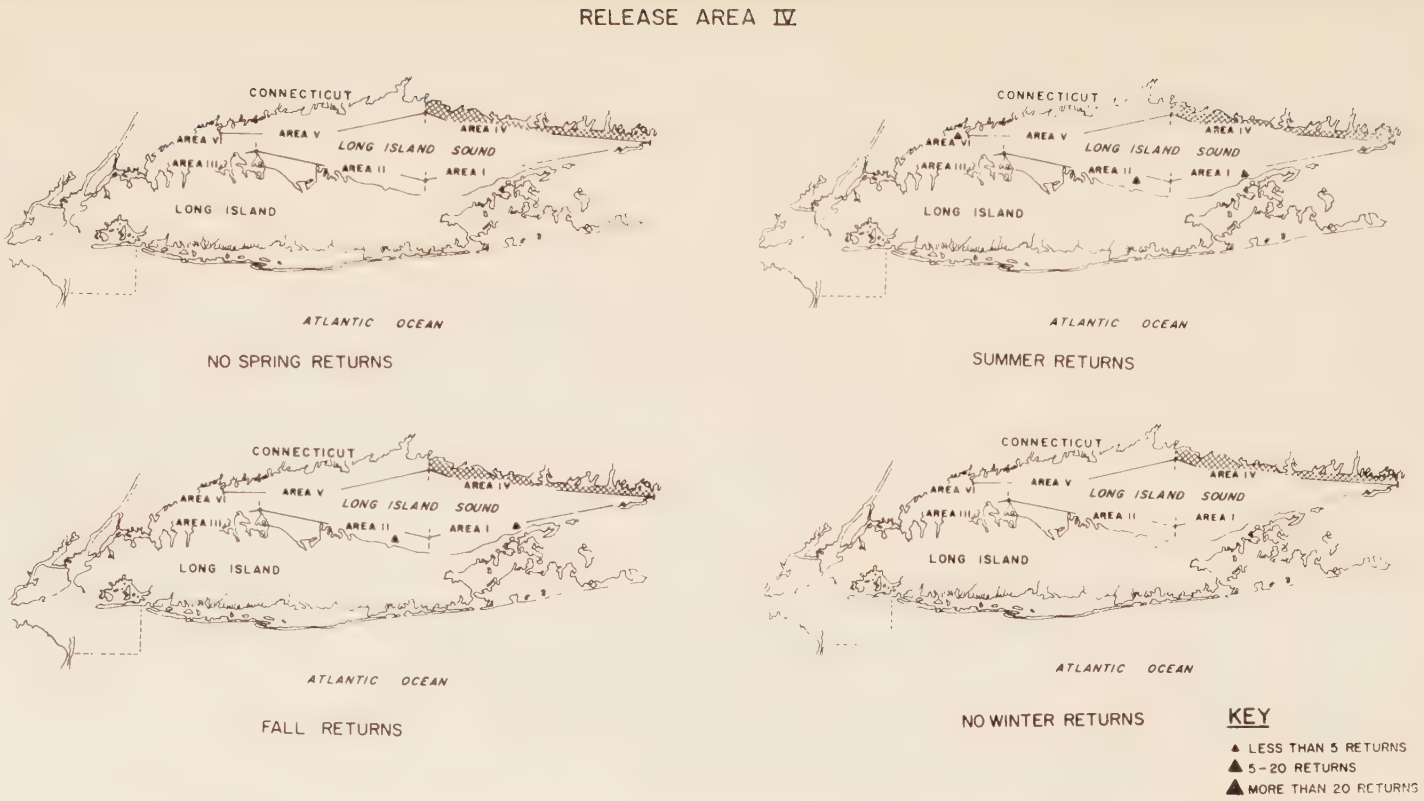


Figure 5. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area IV.

represented fish that had been released in the spring and recovered during the spring or summer, either from within Area IV or from Area V.

Of the fish released in Area IV, 19 were recovered (Figure 5), nine from within that area, two each from Area I, Area II, Rhode Island and the ocean side of Long Island, and one each from Area VI and the Chesapeake region. Of these returns, 88 per cent represented fish that had been released during the spring, with 47 per cent coming from within Area IV during the spring or summer, 31 per cent from Rhode Island or the north shore of Long Island during the summer or fall, and 10 per cent from the ocean side of Long Island during the fall.

Area V

The second greatest number of recoveries (99) were made in this area off the coast of Connecticut between Stamford and Branford (Figure 6), though perhaps significantly 84 of these had also been tagged there. Of the remaining 15, eight had been tagged elsewhere in Long Island Sound, one in Area I, two in Area II, three in Area III and two in Area VI. Of the seven fish recovered in this area that had been released outside the Sound, three had migrated from the Hudson River-New York City area, two from New Jersey, one from the ocean side of Long Island (east of Jones Beach) and one from Rhode Island.

During the period under consideration (1966-1972), 269 striped bass were tagged and released in this area, clearly defining the central Connecticut shore of the Sound as the center of greatest activity under this program of the American Littoral Society. Most were released during the spring and summer (85 per cent), followed by fall (14 per cent) and winter (1 per cent). Of those released during the spring, 55 per cent were recovered within Area V during the spring, summer or fall, the other 45 per cent being recovered during the summer or fall from other areas. Of those released during the summer, 52 per cent were recaptured within Area V in the summer or fall, and 48 per cent were recaptured during these seasons from other areas.

A large number of those released during the summer were recaptured during the fall in Area I (37) and Area II (20), while outside the Sound there were 51 returns from the Chesapeake complex, 36 from the ocean side of Long Island, 13 from North Carolina and nine from the Hudson River-New York City area. Of the fish recovered from North Carolina and the Chesapeake complex, 69 and 62 per cent, respectively, were taken in the winter.

Area VI

A total of 10 fish were recovered in this area along the western north shore of the Sound from Eastchester Bay (N.Y.) to Greenwich (Conn.).

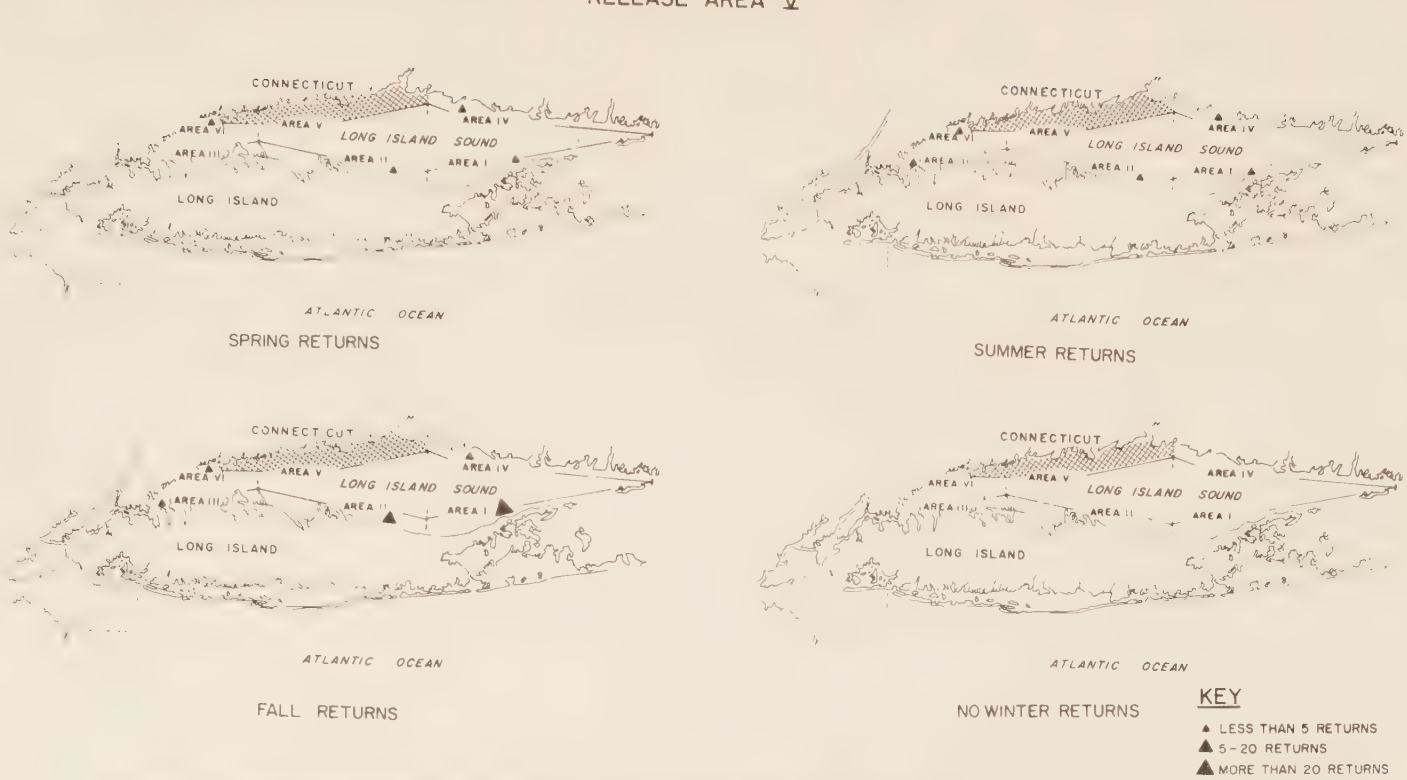


Figure 6. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area V.

Four of these had been released in this area, four had migrated from Area V and two came from other areas in the Sound. Interestingly, there were no recoveries here of fish released in the Hudson River-New York City area.

For fish tagged in Area VI, 20 returns were reported, of which 13 came from within the Sound (Figure 7) and seven from outside it. Of the recoveries, 25 per cent (the greatest proportion from any one area) came from Area I, and all were fish that had been released during the spring or summer and recovered in the fall.

Ocean Side of Long Island (east of Jones Beach and including the east end bays)

Of the 231 striped bass released in the Sound and recaptured outside it, 80 were recovered in this area, of which 57 per cent had been released in Area V along the central Connecticut shore of the Sound and 18 per cent in Area II along the central Long Island shore. For the fish recovered here: 47 per cent were tagged in the summer and recaptured in the fall; 10 per cent were both tagged and recovered during the same fall; 23 per cent were tagged in the spring and recovered in the fall; and 1 per cent were tagged in the winter and retaken in the fall. That 81 per cent of the recoveries on the ocean side occurred in the fall indicated a strong migration from Sound waters via the eastern passages (as indicated also by returns for fish released in Area I) toward wintering grounds farther south.

Hudson River-New York City Area (west of Jones Beach)

For striped bass released in the Sound and recaptured outside it, 5 per cent were recovered in this area. Of these, 75 per cent had been released in Area V and 25 per cent in Areas II, III and VI. The fish were released in spring, summer and fall, with five being recovered in the fall, four in the spring, two in the summer and one in the winter.

As already discussed, five bass recovered in Area I had been released in the Hudson River-New York City area. Also, two fish recovered in Area IV, three recovered in Area V and two recovered in Area III had been released in this area.

New Jersey

Of the bass tagged and released in the Sound and recovered outside it, 17 were taken in New Jersey waters, 70 per cent of which had been released in Area V along the central Connecticut shore. Four fish were released in the summer and recovered in the fall; four were both released and recovered in the fall; one was released in the summer and recovered

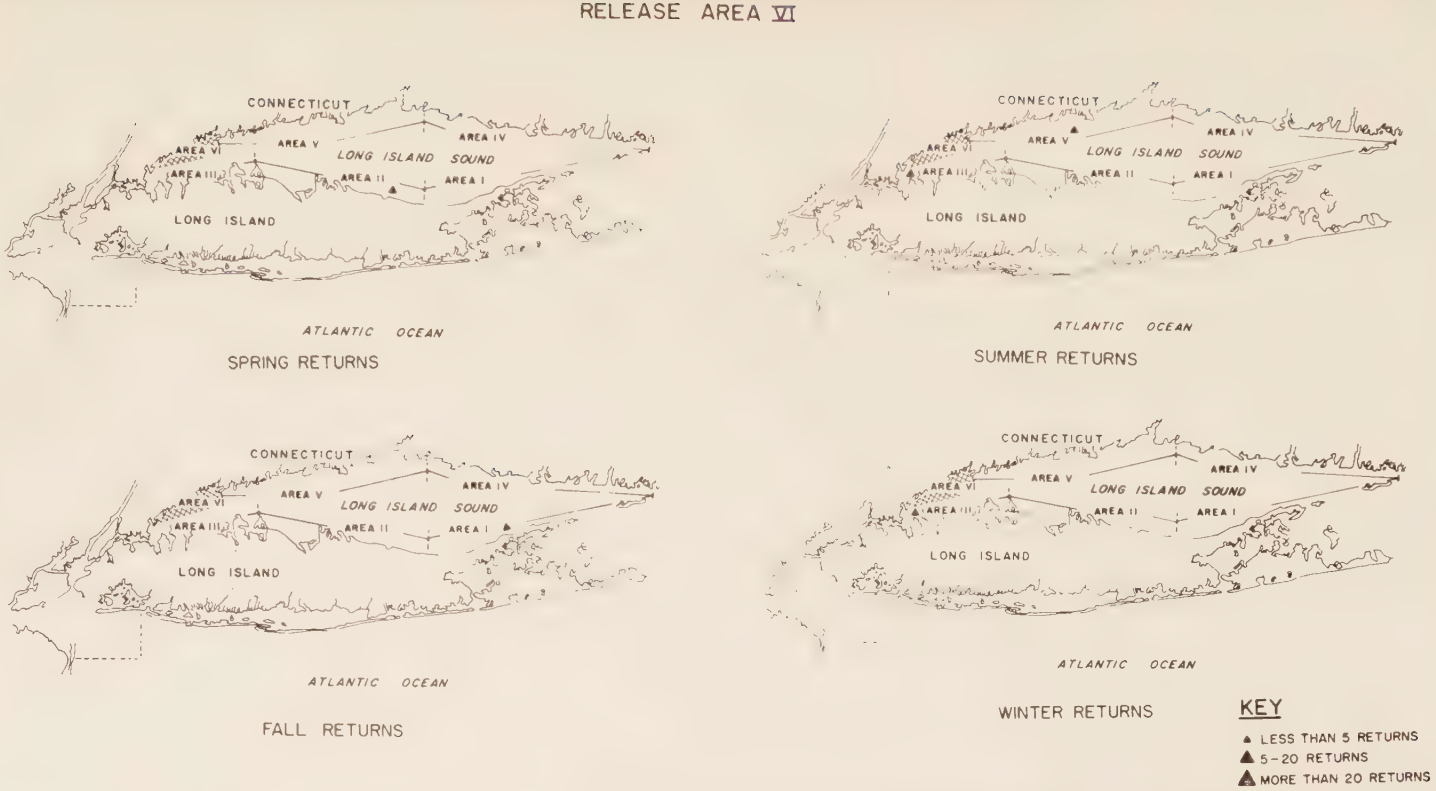


Figure 7. Returns, by season, from other areas in Long Island Sound for striped bass tagged and released in Area VI.

in the winter; and three were released in the spring and recovered in the fall.

Chesapeake Bay (Delmarva area)

A total of 84 bass tagged in the Sound were recovered in this area. Unfortunately, the American Littoral Society did limited tagging there, and there were no returns from the few releases made. Of the 84 fish recovered in the area, 60 per cent had been released in Area V (central Connecticut), 22 per cent in Area II (central Long Island), 14 per cent in Areas III and VI at the western end of the Sound, and 4 per cent in Areas I and IV in the eastern part of the Sound. With respect to season, 55 per cent had been released in the summer and 27 per cent in the fall, while 67 per cent of the recoveries were in the winter, 19 per cent in the spring, 13 per cent in the fall and 1 per cent in the summer.

North Carolina

Of the fish released in Area V (central Connecticut), 13 were recovered in North Carolina waters. All these recoveries were made during the period from late fall through early spring, with 69 per cent being made in the winter.

Massachusetts

Ten returns were reported from Massachusetts, all for fish tagged in the Sound in Areas III, V and VI. Of these, 80 per cent had been released during the spring, half of which were recovered later that spring and half in the summer.

Rhode Island

There were 15 recoveries in Rhode Island waters, all for fish tagged in the Sound. Most of these (73 per cent) had been released in Areas III, V and VI in the western part. Also, 73 per cent had been released in the spring and recaptured during the summer and fall.

DISCUSSION

No attempt has been made in this study to suggest comparative strengths of the southern and Hudson River contingents, as both fishing pressure and tagging efforts were geographically and seasonally selective. The lack of a Hudson River fishery during the months when the fish were in the river wintering grounds makes any comparison of returns impossible. The Hudson River returns were composed of incidental catches by shad fishermen and sport catches, whereas the Chesapeake returns

were primarily from the intense winter and early-spring commercial fishery off mainland Virginia and in the Virginia and Maryland rivers. Of the returns from these two wintering areas, over 90 per cent were from the Chesapeake Bay complex. A substantial number of the returns considered in this study were from the unusually large 1970 year class in the Chesapeake area (Schaefer, 1972) which also may account for the disproportionately large numbers from the southern stock.

The seasonal movement in Long Island Sound appears to have the following pattern. Striped bass enter the Sound in the spring from both ends with attendant movement along the Long Island and Connecticut shores. The greater influx occurs at the eastern end through Plum Gut and the Race. These fish entering via the eastern passages are found throughout the Sound by summer. Those that have entered through the East River also spread throughout the Sound, with some exiting through the eastern passages and continuing northward to Rhode Island and Massachusetts. Most summer recoveries in New England were fish that had been released in the western part of the Sound during the spring. Most of the fish taken in the Sound during the summer were captured along the central Connecticut (Area V) and central Long Island (Area II) shores. This may be attributed to two factors: (1) there were more fishermen in these areas, and (2) these are the most heavily indented stretches of shoreline in the Sound.

There is a fall migration of bass from Massachusetts and Rhode Island into the eastern end of the Sound, while within the Sound proper there is a heavy cross-Sound movement from central Connecticut to Long Island. Fish along the northern shore appear to move from both the eastern and western ends toward the waters off central Connecticut before crossing over to Long Island waters. From there the migration is both west and east, but the principal means of egress appears to be the eastern passages. This is further substantiated by heavy fall returns from the ocean beaches of Long Island and New Jersey for fish that had been released in the Sound during the summer.

Most winter returns were from the Chesapeake area (72 per cent) and North Carolina (11 per cent). However, 7 per cent were from the ocean side of Long Island in March and may have represented an early coastal migration. Of all the winter returns from the Chesapeake area, 49 per cent represented fish that had been released during the summer in waters of the Sound off central Connecticut. But, depending upon variations in year-class strength, these proportions probably fluctuate from year to year.

CONCLUSIONS

The seasonal movement of striped bass in and out of Long Island Sound is well documented. Often alluded to, but neved defined, is an intra-

Sound movement during the summer. The data examined here show a spring influx at both ends, with a larger number entering through the eastern end than enter through the western end. This may, however, depend upon the year-to-year variations in the relative strength of year classes from the Hudson River and Chesapeake areas. The present data do not demonstrate a distinct intra-Sound movement during the summer. The fall migration pattern is striking in that fish in the northern part of the Sound move along the north shore to waters off central Connecticut, then apparently cross in large numbers to the central Long Island shore and finally exit from the Sound at both ends along the northern shore of Long Island, primarily at the eastern end. There were too few recoveries during the winter to establish a pattern, but the fish apparently remain in one locality.

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SKELETAL ABNORMALITIES IN STRIPED BASS[1]

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ABSTRACT

Many types of skeletal anomalies have been reported to exist in fishes, but only one type, pugheadedness, have been previously reported for wild striped bass. The present paper describes 23 anomalous striped bass (ranging in year class from 1964 to 1973) collected during 1973 from localities around Long Island (N.Y.). Pugheadedness was observed in eight adult and six young-of-the-year fish, and four abnormal conditions heretofore unreported for wild striped bass are described: cross-bite, lordosis, scoliosis and abnormal fins. The occurrence of abnormal conditions among hatchery-reared striped bass × white bass hybrids is also noted. Anomalous striped bass are probably more numerous than previous reports tend to indicate. However, all the wild fish examined appeared capable of survival.

Reports of skeletal anomalies of fish are extensive and have been collectively annotated by Dawson (1964, 1966, 1971). For wild populations of striped bass (*Morone savatilis*), the only reports of abnormalities have concerned pugheadedness, which is well documented for the northeastern United States where it has been reported from Chesapeake Bay (Mansueti, 1958, 1960; Schwartz, 1965), the Hudson River and Long Island in New York (Alperin, 1965), Connecticut (Gudger, 1930) and Massachusetts (Mansueti, 1960; Lyman, 1961). The only adequate report of abnormalities among laboratory and hatchery-reared striped bass is that of Mansueti (1958) who described fish with flexed heads, humpbacked bodies, an open-mouthed condition and pugheadedness. Accounts of skeletal abnormalities among wild striped bass have dwelled primarily on descriptions and reports of one or a few individuals, usually from one area.

The present paper describes 23 abnormal indiviuals from many localities around Long Island, New York. Four abnormal conditions previ-

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[1]Contribution No. 66 of the New York Ocean Science Laboratory. The authors wish to express their sincere appreciation to the many fishermen whose help made this study possible and to acknowledge the advice and comments of Dr. Herbert M. Austin, John C. Poole and Albert C. Jensen, the photography by Carl O. Mamay, the graphics by Herbert Weigand, the radiography by Shirley Hunt and Radiological Health Services of the East Hampton Medical Group (East Hampton, N.Y.) and the public relations help of Byron Porterfield. They are also indebted to Dr. Ronal W. Smith of the University of Delaware for use of his data.

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ously unreported in this species are discussed as are degrees of severity where enough information was available. Data are also presented for fingerling striped bass × white bass hybrids, reared at the Morristown Hatchery of the Tennessee Game and Fish Commission, which exhibited many types of skeletal abnormalities during 1967.

METHODS AND MATERIALS

Commencing in November 1972, a program was undertaken by the New York Ocean Science Laboratory to inform sport and commercial fishermen in the Long Island (N.Y.) area of the types of fish deformities sought for scientific investigation. Information, disseminated via the news media (newspapers, periodicals, radio), by distribution of flyers (Figure 1) and by personal contact, resulted in a flurry of finds by fishermen in eastern Long Island the majority of which were striped bass, for which a large fishery exists in the area. In addition, tagging and population studies of striped bass by the State Department of Environmental

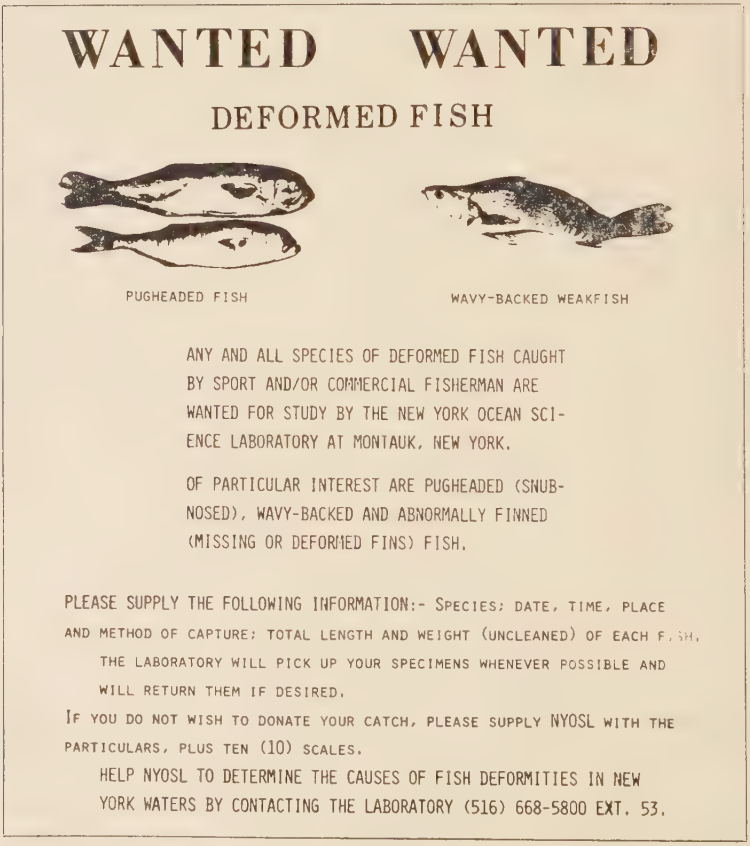
WANTED WANTED
DEFORMED FISH
PUGHEADED FISH
WAVY-BACKED WEAKFISH
ANY AND ALL SPECIES OF DEFORMED FISH CAUGHT BY SPORT AND/OR COMMERCIAL FISHERMAN ARE WANTED FOR STUDY BY THE NEW YORK OCEAN SCIENCE LABORATORY AT MONTAUK, NEW YORK.
OF PARTICULAR INTEREST ARE PUGHEADED (SNUBNOSED), WAVY-BACKED AND ABNORMALLY FINNED (MISSING OR DEFORMED FINS) FISH.
PLEASE SUPPLY THE FOLLOWING INFORMATION:- SPECIES; DATE, TIME, PLACE AND METHOD OF CAPTURE; TOTAL LENGTH AND WEIGHT (UNCLEANED) OF EACH FISH.
THE LABORATORY WILL PICK UP YOUR SPECIMENS WHENEVER POSSIBLE AND WILL RETURN THEM IF DESIRED.
IF YOU DO NOT WISH TO DONATE YOUR CATCH, PLEASE SUPPLY NYOSL WITH THE PARTICULARS, PLUS TEN (10) SCALES.
HELP NYOSL TO DETERMINE THE CAUSES OF FISH DEFORMITIES IN NEW YORK WATERS BY CONTACTING THE LABORATORY (516) 668-5800 EXT. 53.

Figure 1. "Wanted" flyer distributed in the eastern Long Island area.

Conservation in the lower Hudson River and in the East Hampton-Montauk (Long Island) areas resulted in the capture of deformed striped bass. Hudson River fish were captured by a 100 x 10-foot beach seine having ¼-inch mesh, while those captured in waters of eastern Long Island were taken by commercial haul seine in cooperation with local fishermen. Fork lengths were measured to the nearest millimeter, weight was taken to the nearest gram and age was determined by the scale method. These data were not available for a few fish that had been cleaned before examination. Data supplied by fishermen in inches and pounds were converted to metric measurements.

RESULTS AND DISCUSSION

A total of 23 wild striped bass, exhibiting five types of skeletal deformities, were recorded and are discussed according to the type of anomaly. The data are summarized in Table 1, and the number assigned to each specimen is used in referring to it throughout the text and corresponds to its capture location as shown in Figure 2.

Pugheadedness

Pugheadedness among striped bass has previously been described (Sutton, 1913; Gudger, 1930; Mansueti, 1960; Alperin, 1965; Schwartz, 1965; Hickey, 1973), but only in the extreme condition. The 14 pugheaded wild striped bass examined in this study exhibited various degrees of the condition, from mild to very severe. It became evident that the term "pugheaded" did not adequately describe this abnormal condition. Gudger (1929) described two degrees of pugheadedness among salmonids, both being extreme cases. In the present study, the specimens were divided into three categories based on the observed external deformities of the skull, jaws and eyes. Following are the characteristics of each:

Primary pugheadedness (Figure 3)

(1) mildly steep forehead only

Secondary pugheadedness (Figures 3 and 4)

(1) moderately steep forehead
(2) slight reduction in size of upper jaw, so that lower jaw protrudes beyond upper slightly more than normal
(3) possible malformation of maxilla and premaxilla bones
(4) with or without exophthalmia (bulging eyeballs)

Teritary pugheadedness (Figure 3)

(1) acutely steep forehead
(2) greatly reduced upper jaw with

Table 1. Place and Date of Capture and Physical Data For Deformed Striped Bass From Long Island and the Hudson River (N.Y.), According to Type of Deformity

Number and place of capture*	Date	Fork length (millimeters)	Weight (grams)	Age	Year class
Primary pugheadedness					
1 Montauk	June 15, 1973	420	750	3+	1970
Secondary pugheadedness					
2 Pollock Rip (Montauk)	June 15, 1973	756	5,448	7+	1966
3 " " "	Sept. 5, 1973	876	..	8+	1965
4 Reeves Bay (Riverhead)	May 12, 1973	370	643	2+	1971
5 Hudson River	Sept. 6, 1973	70	5	0+	1973
6§ " "	Oct. 4, 1973	88	8	0+	1973
7§ " "	Oct. 18, 1973	80	6	0+	1973
8 " "	Nov. 1, 1973	57	..	0+	1973
9§ " "	Nov. 16, 1973	85	6	0+	1973
10§ " "	Dec. 13, 1973	93	9	0+	1973
Tertiary pugheadedness					
11 Central Long Island Sound	Summer 1970	630	2,726	6+	1964
12 Montauk Point	Oct. 2, 1970	..	4,540	..	..
13 West Meadow Beach	May 22, 1973	590	2,820	6+	1967
14 East Hampton	Nov. 11, 1973	415	940	2+	1971
Semi-cross-bite					
15§ Montauk	Nov. 7, 1973	465	1,135	3+	1970
16§ Napeague	Nov. 10, 1973	385	681	2+	1971
17 "	Nov. 17, 1973	585	2,025	6+	1967
Full cross-bite					
18 Amagansett	July 25, 1973	780	6,221	..	..
19 Three Mile Harbor	Nov. 15, 1973	360	432	2+	1971
Lordosis					
20 Montauk Point	June 15, 1973	580	2,633†	6+	1967
21 Cedar Beach	Nov. 24, 1973	457	..	..	..
Lordosis and scoliosis					
22 Culloden Point (Montauk)	Oct. 27, 1973	425	1,009	3+	1970
Abnormal fin					
23 Amagansett	Nov. 5, 1973	555	1,874	5+	1968

* Number corresponds to capture location in Figure 2.
§ Tagged and released.
† Fish partially eviscerated before weighing.

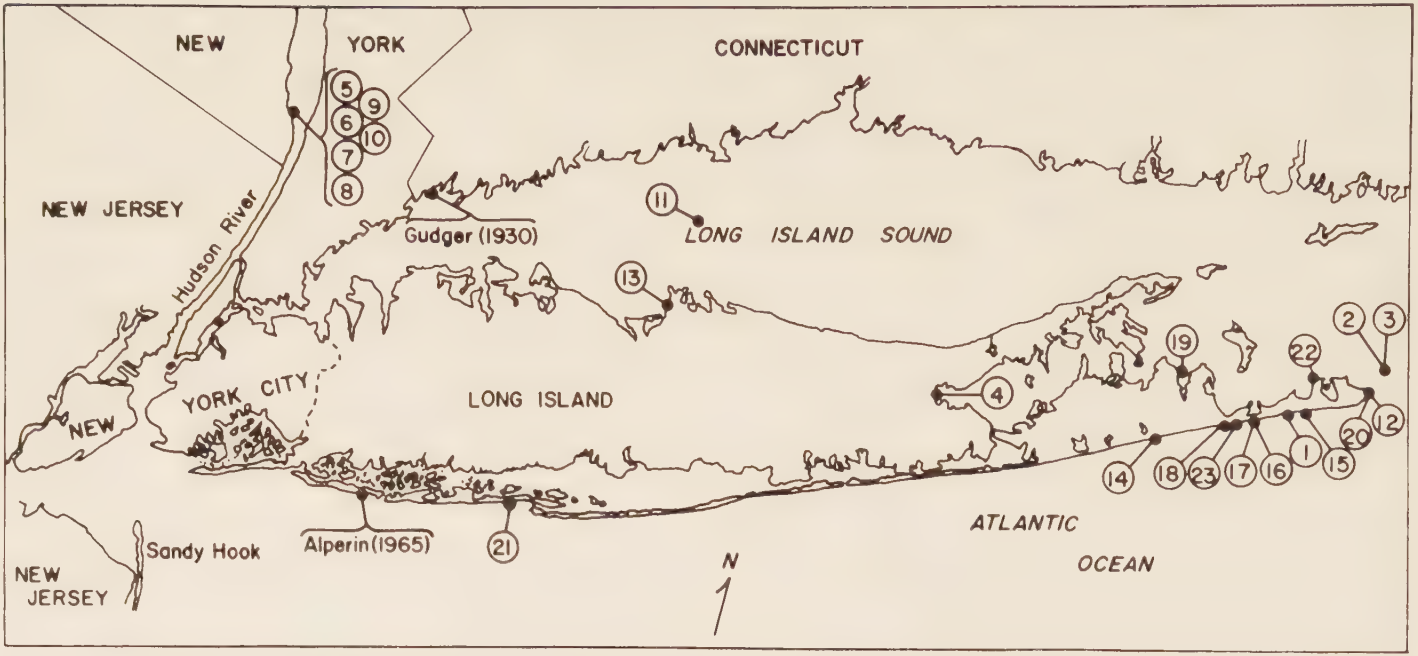

Figure 2. Locations where deformed striped bass were captured in the Long Island-Hudson River area. Circled numbers correspond to those given in Table 1 and in the text and other figure captions to represent both the site and the individual fish. Also shown are the areas where pugheaded striped bass were reported by Gudger (1930) and (Alperin (1965).

(a) lower jaw extending far beyond upper
(b) malformation of maxilla and/or premaxilla bones
(c) incomplete closure of mouth
(d) reduced gape
(e) exposure of tongue

(3) exophthalmia

Primary pugheadedness was observed in one individual (fish No. 1) taken by commercial haul seine. An age 3+ female, it was just below the mean weight for this age group as given by Mansueti (1961) and below that for a fish of its length as reported by Merriman (1941).

Secondary pugheadedness was observed in nine striped bass. Fish Nos. 2, 3 and 4, all adults, were all taken by angling and were of normal size for their age groups when compared with the data of Merriman (1941) and Mansueti (1961). The pugheaded condition of fish No. 2 was accompanied by jaw malformations. The right premaxilla and maxilla were absent and, as a result, the lower jaw was skewed upward on the right side presumably to fill the empty gap. The left maxilla was bent inward and tucked behind the articular bone so that its normally exposed ventral tip was no longer visible. This also caused the left dentary to be bent inward.

Six young-of-the-year striped bass (Nos. 5-10), all of the 1973 year class, that exhibited secondary pugheadedness were captured on various dates by beach seine in the lower Hudson River (Figure 2). Catch statistics were recorded only for those fish of taggable size (>80 millimeters), and of 1,773 fish tagged, four (0.2 per cent) were pugheaded. Fish No. 6 was one (0.4 per cent) of 276 tagged on the same day and was comparable in size to its normal cohorts. Fish No. 7 was one (1.9 per cent) of 53 and was below the mean length (85.1 millimeters) and mean weight (8.44 grams) of its normal cohorts. Fish No. 9 was one 0.8 per cent) of 131 and was also below the mean length (93.2 millimeters) and mean weight (8.99 grams) of its normal cohorts. Fish No. 10 was one (25.0 per cent) of four and was the largest and only fish of taggable size in that particular catch. Fish No. 5 (Figure 4) and No. 8 were below taggable size, but they were recognized and retained although their normal cohorts were not enumerated. All of the pugheaded young-of-the-year fish appeared healthy and active.

Tertiary pugheadedness was observed in four striped bass. Fish No. 11 was taken by gill net in 1970 and was frozen for about 2 years before our examination. It was slightly shorter than the average for fish of age group 6+ as reported by Mansueti (1961), although its weight was normal. It was lighter (by about 1 pound) than fish of its length as noted by Merriman (1941). Fish No. 12 was taken by angling, and only a photograph

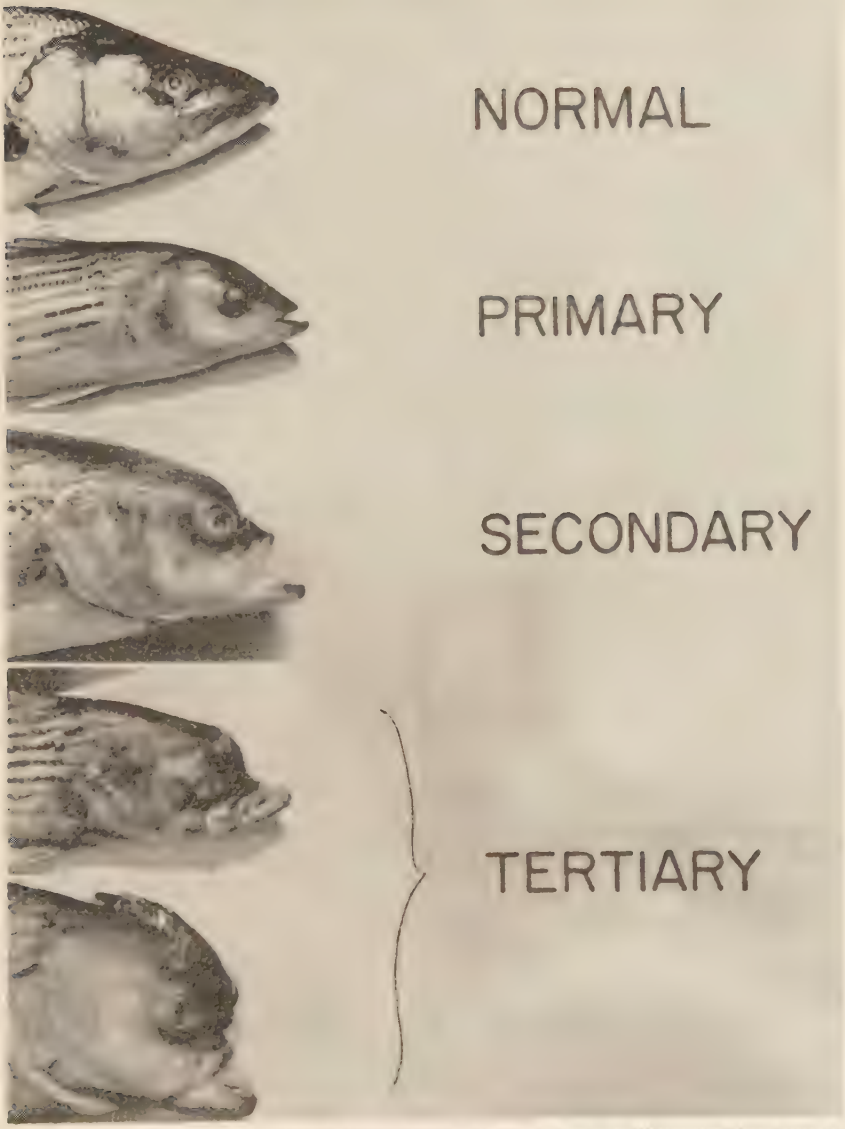

Figure 2. Degrees of pugheadedness among striped bass as illustrated by (top to bottom) normal fish, primary (fish No. 1), secondary (fish No. 4) and tertiary (fish Nos. 14 and 13). Fish No. 13 displays an injured skull as a result of being captured by spear.

was available to the authors. Although neither length nor age were known, the weight was given as 10 pounds (4,540 grams) and the fish appeared healthy. Fish No. 13 (Figure 3), a female (age 6+), had been speared and was slightly heavier than fish of comparable size as

Figure 4. Secondary pugheadedness (top—fish No. 5) and normal condition (bottom) in young-of-the-year striped bass from the Hudson River.

given by Merriman (1941), but compared with data reported by Mansueti (1961) its length was more nearly that of an age 5+ fish although its weight was normal. Fish No. 14 (Figure 3) was a male captured by commercial haul seine and was of normal size for fish of age group 2+.

Although some of these 14 pugheaded striped bass were slightly smaller than normal in size, all appeared healthy and vigorous. Those captured by angling apparently had little difficulty attacking a lure and all fought well. It is apparent from these data and from the large size of some of these fish that they were capable of feeding efficiently and competing with their normal peers. Fish No. 8, a young-of-the-year specimen, was held alive in the laboratory along with about three dozen of its cohorts for over 10 weeks. During that time, the pugheaded individual fed with as much vigor as normal fish and behaved similarly. Mansueti (1958) described normal feeding behavior for pugheaded striped bass in the laboratory.

Pugheaded striped bass have been reported from several localities in the northeastern United States, but their origins are indicated only by the reports for young-of-the-year fish. Alperin (1965) reported a juvenile from the Hudson River in New York and Mansueti (1960) reported two from the Elk River in Maryland. Ronal W. Smith of the University of Delaware stated (personal communication) that pugheaded and wavy-backed striped bass have been caught in Delaware Bay, in the Chesapeake and Delaware Canal and in the Delaware River in the vicinity of the

Canal. These conditions were found in less than 1 per cent of the specimens examined and were observed in juveniles or fish under 25 centimeters in length, although they occurred most often in fish 8 to 15 centimeters long. It is evident, therefore, that pugheaded striped bass have originated from the three major stocks of the northeastern United States, i.e., those of the Hudson River, Delaware Bay and Chesapeake Bay.

The causes of pugheadedness were discussed in some detail by Hickey (1973), but the exact causes of this anomaly in natural populations of striped bass are as yet undetermined. If environmental factors are involved, as suggested by Mansueti (1958), it would appear likely that similar conditions exist in these three nursery grounds, which induce the formation of pugheadedness. Conversely, if the anomaly has genetic origins, it may arise from spawning populations in any location.

A review of the available literature on wild pugheaded striped bass revealed that all of the reports containing adequate descriptions or illustrations pertained to the tertiary condition. This is probably due to the very striking and peculiar features of such fish which make them easily recognized and arouse the interest of the layman, who supplied many of the specimens. Less severe pugheaded conditions may arouse little interest or be overlooked by the uninformed fisherman.

Cross-bite

Cross-bite is a deformity in which the lower jaw (in whole or part) is skewed off center or laterally displaced so that it appears bent, crooked or crossed. This condition has been described for menhaden (*Brevoortia tyrannus*) by Merriner and Wilson (1972) and for the orangemouth corvina (*Cynoscion xanthulus*) by Whitney (1961), but not for striped bass. In the present study, five such striped bass were examined (Table 1) and an additional one was seen in a commercial packing house for which no data were available. Of those examined, four (Nos. 15-18) were captured by commercial haul seine and the fifth (No. 19) by pound net. None was taken by angling which would require normal mouth operations in order to attack and become hooked on the fisherman's lure.

Several degrees of this deformity were evident, but it was classified into two groups for convenience: full cross-bite and semi-cross-bite, the former being the more severe. In the full cross-bite condition, the dentaries are anteriorly detached from each other and both bend inward, thus either crossing or paralleling each other (Figure 5). In the semi-cross-bite condition, either the entire lower jay is laterally displaced from the midbody axis or the dentaries are anteriorly detached with only one being laterally displaced and the other normal (Figure 5).

Three striped bass exhibiting the semi-cross-bite condition were exam-

Figure 5. Degrees of cross-bite among striped bass as illustrated by: (A) normal fish; (B) semi-cross-bite (fish No. 17); and (C) full cross-bite (fish No. 19).

ined. In fish No. 15, the entire lower jaw was skewed approximately 30° to the right. The jaw was of normal size and shape with apparently normal or nearly normal movement. In fish No. 16, the right dentary was unattached from and crossed under a normal left dentary at approximately 45°. Both of these fish appeared healthy and of normal size for their age groups. In fish No. 17, the entire lower jaw was reduced in size and skewed approximately 30° to the left (B in Figure 5). There appeared to be incomplete closure of the mouth with a reduced gape. An age 6+ female, this fish was smaller than normal, being near the size of age 5 to 5+ fish as described by Mansueti (1961) and considerably lighter for its length than the average as reported by Merriman (1964).

Two specimens having the full cross-bite condition were examined. In fish No. 18, both dentaries were bent inward paralleling each other at approximately right angles to the midbody axis. These bones were probably immovable or nearly so, yet the fish appeared healthy and was of normal weight for its length as given by Merriman (1941) and Mansueti (1961). In fish No. 19, the left dentary was skewed approximately 45° to the right, and the right dentary was skewed approximately 60° to the left, of the midbody axis. The left maxillary was smaller than normal, and the entire mouth opening and gape were severely reduced (C in Figure 5). A male, this fish was extremely thin and smaller than the average for age group 2+ as given by Merriman (1941) and Mansueti (1961). It was about the size of a 2 year old (about a 6-month difference). This appeared to be the most frail and unhealthy of all the deformed striped bass examined during the study.

It is not known whether these conditions are the result of injury, ge-

netic factors or environmental circumstances. Merriner and Wilson (1972) stated that in menhaden cross-bite did not appear to be injury-induced. Their report was on a semi-cross-bite condition with the entire jaw skewed off center, rather than the more severe full cross-bite anomaly. The latter condition has the appearance of being injury-related, but none of the striped bass examined during the present study had wounds about their mouths or signs of such injury. It is possible that during embryological development their dentaries failed to fuse.

Lordosis and Scoliosis

Spinal curvature among natural fish populations has been reported for many species, but heretofore it has not been reported for the striped bass. Three such individuals were found in this study, two with lordosis (vertical spinal flexure) and one with lordosis plus scoliosis (lateral spinal flexure). All were taken with hook and line by surfcasters and were as aggressive in their fight as normal fish.

The lordotic condition of fish No. 20 was a mild ventral flexure at the caudal peduncle (Figure 6). This fish (age 6+) had been partially eviscerated before examination, so accurate weight comparisons were not possible. Length comparisons, however, indicated that it was near the size of age group 5+ as described by Mansueti (1961), while it fell within the limits of age group 6+ as given by Merriman (1941).

Fish No. 21 possessed a ventral flexure which began just behind the first dorsal fin, dipped at about a 45° angle for 4 centimeters and returned to a normal position just posterior to the forward origin of the second dorsal fin. The result was the appearance of a notch between the two dorsal fins. Although no weight or age was available, the captor reported that the fish appeared quite robust and healthy.

Fish No. 22 was lordotic dorsally in the region of the first dorsal fin giving it a mildly humpbacked appearance, and ventrally in the region of the second dorsal fin. It also possessed a scoliotic flexure to the left in

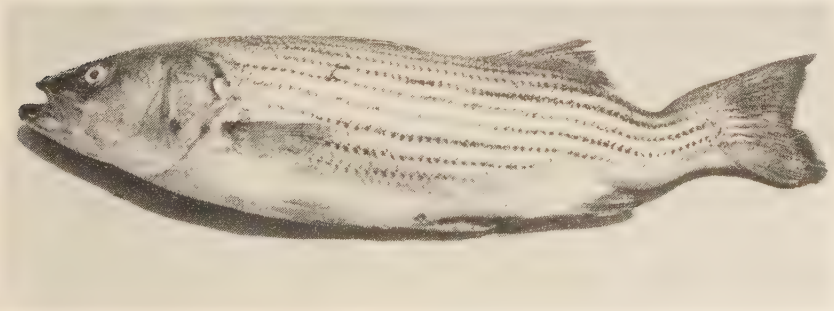

Figure 6. Mild lordosis at the caudal peduncle (fish No. 20).

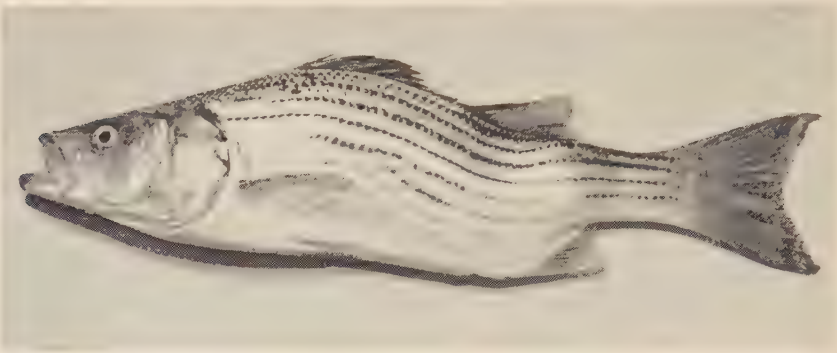

Figure 7. Lordosis in the region of the first dorsal fin and scoliosis just anterior to the caudal peduncle (fish No. 22).

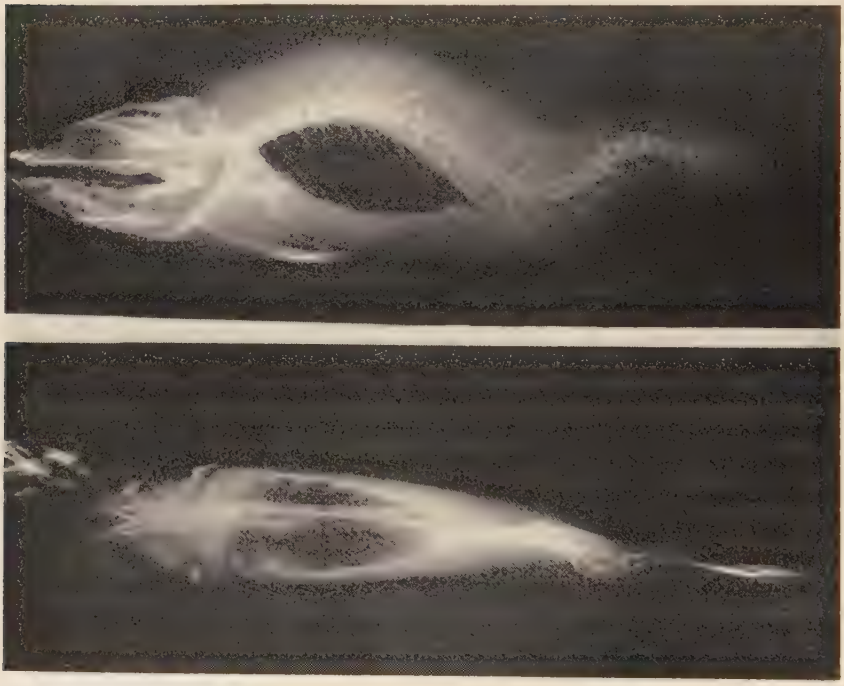

Figure 8. Radiographs of striped bass No. 22. Lateral view (top) depicts lordosis, while dorsal view (bottom) depicts scoliosis.

the region between the posterior margins of the second dorsal and anal fins (Figure 7). Radiographic examination revealed a more severely flexed spinal column than was expected from external examination (Figure 8). Its length and weight fell within the limits for age group 3+ as described by Merriman (1941) and Mansueti (1961).

The exact causes of spinal curvature among natural fish populations are uncertain, but it appears to be of genetic origin or environmentally induced rather than to occur as a result of injury. The causes and effects of spinal abnormalities in fishes were discussed in some detail by Hickey (1973).

Abnormal Fins

Hickey (1973) also discussed the causes and effects of abnormal fins in fish, but prior to the present study this condition had not been reported among striped bass. In fish No. 23, the first dorsal fin consisted of five spiny rays (actinotrichia) rather than the normal complement of nine (range of 8-10: Bigelow and Schroeder, 1953; Mansueti, 1958; Leim and Scott, 1966). The missing rays were the anterior four. Radiographic examination also revealed the absence of two supporting pterygiophores (Figure 9). As there was no evidence of scar tissue, abnormal scale pat-

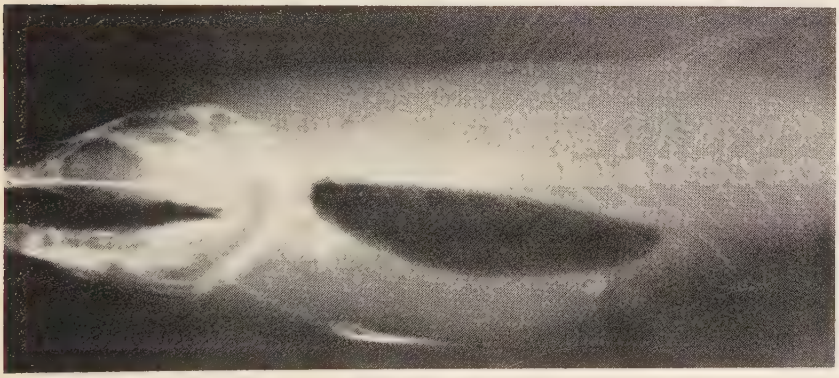

Figure 9. Radiograph of striped bass No. 23 showing absence of the anterior four spiny rays and two pterygiophores of the first dorsal fin.

terns or abnormal coloration in the area surrounding the first dorsal fin, this anomaly probably was not the result of injury. Similarly, Dahlberg (1970) concluded that, due to the absence of scar tissue and abnormal scales, a fin abnormality of the southern kingfish (*Menticirrhus americanus*) was an anomaly rather than the result of injury.

This fish was in a catch of 100-150 striped bass taken by commercial haul seine and was among the largest of the catch. Comparison with the length and weight data of Merriman (1941) showed that it was somewhat lighter than the average for its length, while in relation to the data of Mansueti (1961) it was of normal size for an age 5+ female. It seems probable that this fish suffered no unusual effects from this mild fin anomaly.

Abnormalities Among Hatchery-reared Striped Bass × White Bass Hybrids

During 1967, there were two occurrences at the Morristown Hatchery of the Tennessee Game and Fish Commission in which more than 75 per cent of pond-reared fingerling hybrids displayed skeletal deformities. In one pond, 20,000 of 24,000 such fingerlings (white bass male × striped bass female) had a "sucker-mouthed" condition in which the lower jaw was reduced and the opercles were locked in an extended position (A in Figure 10). Backcrossing (hybrid male × striped bass female) produced various degrees of skeletal deformity, including tertiary pugheadedness as well as lordosis and scoliosis (B and D in Figure 10).

Earlier, Mansueti (1958) reported that several humpbacked (lordotic)

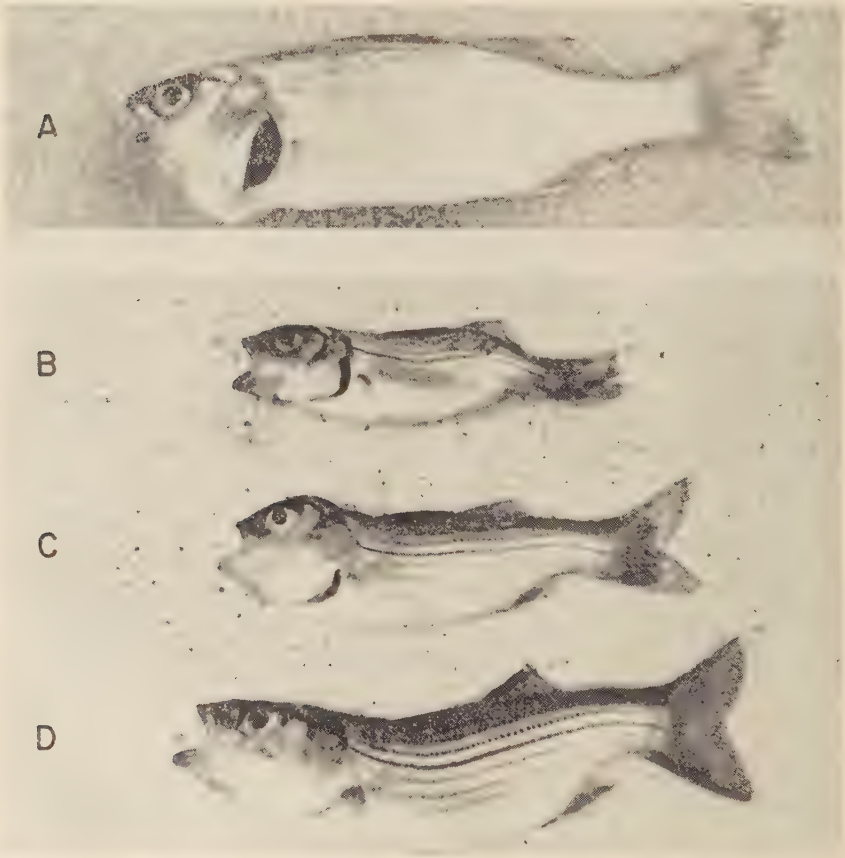

Figure 10. Abnormalities among hatchery-reared fingerling hybrids (striped bass X white bass): (A) "sucker-mouthed" condition with extended and locked opercles; (B) scoliosis; (C) dorsally flexed head; and (D) lordosis.

striped bass larvae had been produced under laboratory conditions, probably as a result of varying environmental factors. He also reported that, during the summer of 1956, about one-third of surviving hatchery-reared young were pugheaded, but he did not note either the name or location of the hatchery.

Another deformity displayed by some backcrossed fingerlings at the Morristown Hatchery was a dorsally flexed head with a slightly reduced upper jaw (C in Figure 10), which gave them a primary pugheaded appearance. This condition was strikingly similar to that of abnormal striped bass larvae with blue-sac disease as described and illustrated by Mansueti (1958). As primary pugheadedness had not been described at the time, no records were kept of its degree of occurrence among the hatchery fingerlings. One generation, however, contained several hundred fingerlings that appeared to have a steeper than normal angle from the nares to the posterior end of the skull, giving them a primary pugheaded appearance. Those fish grew as well as their normal cohorts and did not appear to be adversely affected by their condition.

Only during 1967 were mass abnormalities produced at the Morristown Hatchery, and it is not known whether they were genetic in nature. It is interesting that there are less than a dozen reports of deformities from wild populations of striped bass in Tennessee, which suggests that: (1) wild striped bass and white bass interbreed very little or not at all, producing few or no abnormal individuals; (2) any abnormal fish may be competitively weak and therefore are culled by natural selection processes; (3) intraspecific competition is less severe under hatchery conditions than in the natural environment, thus allowing a greater manifestation of abnormalities among hatchery fish; (4) environmental conditions within the hatchery may contribute to the production of abnormalities; (5) fishermen either seldom catch abnormal fish or do not report those they do catch.

CONCLUSIONS

Enlisting the cooperation of the public along with that of the scientist-fisherman was effective for finding abnormal striped bass, as evidenced by the large number reported and the discovery of types of deformity previously unreported for this species. Many more deformed striped bass probably exist than the usual volume of reports would indicate. The greater the total number of specimens examined, the more representative become the data concerning the occurrence and significance of abnormalities.

The deformed wild fish noted during the present study ranged in year class from 1964 to 1973, indicating that such individuals are continually being produced. Although more specific information is needed, it appears likely that the abnormal conditions discussed do not markedly alter the

recruitment of affected striped bass into the fishery, either sport or commercial. They may, however, reduce the marketability of fish sold in the round (uncleaned) due to their bizarre appearance. Even though some were smaller than average for their age, presumably as a result of their abnormal condition, all of the deformed striped bass were obviously capable of survival. This was evident from the presence of large fish on the summer feeding grounds of the Long Island area, and by the observed feeding capacity of deformed young of the year and specimens taken by angling. Reports of stunted striped bass resulting from pugheadedness (Alperin, 1965), blindness (Denoncourt and Bason, 1970) and jaw injury (Hickey and Amish, 1975), together with the present findings, suggest that this species is quite hardy and capable of survival under conditions of severe physical handicap.

As abnormal striped bass are found in stocks under laboratory (Mansueti, 1958; Turner and Farley, 1971), hatchery and natural environmental conditions, and as these fish appear to be hardy, this species may well be an ideal experimental animal for studies of the causes and effects of abnormalities in fishes. Further information is needed from the areas in which abnormal striped bass originate. A detailed examination of young-of-the-year fish in their nursery-ground areas would make it possible to define the occurrence and distribution of abnormalities, their degree of severity, and perhaps types that exist in juveniles which are competitively weeded out and therefore are not found in older fish. Laboratory studies might also shed light on the causes of various abnormality types as well as their effects on individual fish.

Very few books or major publications on fish diseases dwell at any length on physical abnormalities, primarily because their causes are variable and uncertain and because there is generally no treatment or cure for such conditions. All too often affected fish have been treated merely as subjects of interest or curiosity rather than as handicaped or diseased animals. A more thorough understanding of these abnormalities and their effects on fish, as well as of the possibility of treating them in a more clinical manner, would be desirable.

Knowledge of the normal occurrence of abnormalities in fish is important in evaluating allegations that their incidence is increasing. The causes of skeletal changes are said to be associated with increasing pollution by petroleum and other substances. The proliferation of nuclear power plants with their discharges of radio-nuclides also is cited as a potential for serious genetic and morphological changes in marine organisms. Data of the sort presented here will provide a yardstick against which to measure future conditions.

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EFFECT OF FEEDING CANNED KERNEL CORN ON THE CONDITION OF WINTER FLOUNDER[1]

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ABSTRACT

Canned kernel corn was fed to winter flounders to simulate the chum used in the sport fishery. Corn constituting up to 80 per cent of the diet neither altered the condition factor nor killed the fish.

The use of canned kernel corn (*Zea mays*) as chum or attractant in fishing for winter flounders (*Pseudopleuronectes americanus*) has stirred debate among saltwater anglers. Some anglers claim that the ingested corn kills the fish, that winter flounders cannot digest corn, that corn clogs the stomach and blocks the intestine or that ingested corn will swell and cause the stomach and/or intestine to burst. Others claims that corn does no damage to winter flounders and is a cheaper, acceptable substitute for more expensive "natural" chum such as crushed ribbed mussels (*Modiolus demissus*) and blue mussels (*Mytilus edulis*). Prompted by this controversy, the Department undertook a study to find out whether or not the ingestion of canned kernel corn is harmful to winter flounders.

MATERIALS AND METHODS

Winter flounders were collected by otter trawl from Moriches Bay on the southern shore of Long Island and transported by tank truck to the Department's Marine Laboratory at Flax Pond near Setauket on April 16, 1974. These fish ranged from 230 to 340 millimeters (average = 283 millimeters) in total length. The mean length and size distribution approximated the modal length and size distribution of those caught by anglers in Moriches Bay as reported by Briggs (1965). The fish were probably between ages II+ and VII+ as described by Poole (1966).

At the laboratory, the fish were placed in a plywood holding tank 428 centimeters long and 89 centimeters wide with a water depth of 52 centimeters. This tank was part of flow-through system and received water at the rate of 5.7 liters per minute. After acclimitization, they were measured to the nearest millimeter in total length, weighed to the nearest gram and put into smaller experimental tanks on May 2, 1974. Each fish received a differently colored (red, green, blue, yellow or beige) or modified ("flag" clipped off) Floy FD67F anchor tag to facilitate recognition of individuals.

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[1] Contribution No. 77-1 of the Division of Marine and Coastal Resources.

Thus, 10 differently marked winter flounders were put into each of four interconnected plywood experimental tanks that measured 121 centimeters long and had the same width and depth as the holding tank. Water was pumped through these tanks at a rate of approximately 5.7 liters per minute. Salinity was about 25 ppt, and the water temperature ranged from 16° to 19° C. during the experiment. A layer of gravel approximately 5 centimeters deep covered about half the floor of each tank. The whole floor was not covered in order to facilitate cleaning the tanks and to reduce turbidity in them near the water intake.

The flounders in each tank received a different combination of shucked shellfish (hard clams (*Mercenaria mercenaria*), ribbed mussels and blue mussels) and canned kernel corn for food. The ration was equal to 7 per cent of the total body weight of the fish in a given tank. The fish in Tank 1 received 50 per cent shellfish (88 grams) and 50 per cent corn (88 grams). The fish in Tank 2 (the control) received 100 per cent shellfish (193 grams). The fish in Tank 3 received 20 per cent shellfish (38 grams) and 80 per cent corn (152 grams). The fish in Tank 4 received 80 per cent shellfish (135 grams) and 20 per cent corn (34 grams). The fish were fed daily from Monday through Friday and once on weekends.

No fish were fed 100 per cent corn because it would be impossible for winter flounders to find a natural environment where the only food available to them was corn. Indeed, the author feels that even the mixture

Table 1. Condition Factor For Each Winter Flounder at Start and Finish of Experiment (May 2-June 4, 1974)

Tank	Condition factor (*K*)		Tank	Condition factor (*K*)	
	At start	At finish		At start	At finish
Tank 1	0.86	0.91	Tank 3	1.07	1.18
	1.14	1.09		1.19	1.14
	1.11	1.07		1.09	1.18*
	1.06	1.00		1.16	1.21
	1.12	1.05		1.25	1.17
	0.94	0.96		1.18	1.12
	1.21	1.08		1.23	1.21
	0.98	0.88		1.16	1.03
	0.96	0.93		1.05	1.10
	1.24	1.11		1.26	1.26
Tank 2	1.32	1.41	Tank 4	0.94	0.89§
	1.30	1.42		1.18	1.07
	1.01	1.17		1.32	1.26
	1.05	1.13		1.15	1.71
	0.80	0.54		0.97	0.99*
	1.02	1.04		0.94	0.97
	0.94	1.03		1.26	1.23
	1.28	1.24		1.20	1.15
	1.33	1.30		1.26	1.10
	0.93	0.93		1.14	1.09

* Fish died May 5.
§ Fish died May 18.

consisting of 80 per cent shellfish and 20 per cent corn provided more corn to the fish than could be found in any natural area no matter how heavily anglers chummed such an area.

An attempt was made to remove all uneaten food prior to introducing new food. However, since pieces of shellfish or kernels of corn sometimes lodged in the gravel in the tank, it was never possible to remove and weigh all the uneaten food. At the conclusion of the experiment on June 4, 1974, the flounders were again measured and weighed. Fish were not sacrificed during the experiment to examine the digestive tract for the type of food eaten because of the small number involved.

Since shrinkage has been shown to occur in tagged flatfishes (Graham, 1956; Kotthaus, 1963), lengths and/or weights measured before and after the experiment could not be used alone to determine any gross effects of feeding corn to winter flounders. Instead, the condition factor (K) was calculated for each fish and an average value for all the fish in each tank was determined at the start and at the finsh of the experiment. The formula given in Rounsefell and Everhart (1953) was used, i.e.

$$K = \frac{100{,}000\ W}{L^3}$$

where:

K = condition factor
W = weight in grams
L = length in millimeters

Use of this formula minimized difficulties in analyzing raw data in cases where a fish, although it had shrunk, was actually in better physical condition at the end of the experiment than at the start.

A prior attempt at this experiment had been started on June 11, 1973 using fish of similar sizes taken by trawling in Great South Bay and Moriches Bay. Unfortunately, all these fish were lost due to a water supply failure over the weekend of June 22-25. Because of the condition of many of the carcasses, it was not possible to weigh or measure the specimens to calculate K-values at the end of this aborted experiment. However, digestive tracts of the dead fish were examined to determine what food had been ingested.

RESULTS

Eight of the winter flounders that died in the aborted 1973 experiment had food in their stomachs and/or intestines. In five of these, canned kernel corn in various states of digestion was the only food present. One of the others had eaten both corn and ribbed mussel, and two had eaten only ribbed mussel. Seven fish were too decomposed to examine for

Table 2. Mean Condition Factor For Winter Flounders in Each Tank at Start and Finish of Experiment and *t*-Values For Degree of Change

Tank	Mean condition factor (K)		t-Value	
	At start	At finish	From data	For significance*
Tank 1	1.06	1.01	1.72	2.10
Tank 2	1.10	1.12	0.30	2.10
Tank 3	1.16	1.16§	0.00	2.11
Tank 4	1.14	1.20§	1.13	2.12

* Value required for significance at 95 per cent level of confidence.
§ Excluding fish that died during the experiment.

stomach contents. The remainder (25) had no food in their digestive tracts.

The condition of each fish at the start and end of the 1974 experiment is shown in Table 1. With two exceptions, the changes in condition were slight. One exception was a fish, fed a diet of 100 per cent shellfish, that declined from a K-value of 0.80 to one of 0.54 during the experiment. The other was a fish, fed a diet of 80 per cent shellfish and 20 per cent corn, that increased from a K-value of 1.15 to one of 1.71. It is interesting that both of these fish had shrunk 5 millimeters in length and that one lost 58 grams in weight while the other gained 82 grams.

Increases and decreases in the K-value for individual winter flounders may only reflect normal variations that might be expected in nature and could not be treated statistically. Therefore, to see if there were any real trends, the mean K-values for all the fish in each tank before and after the experiment were subjected to t-tests (Table 2). No matter which food mixture was considered, there was no significant change in the mean condition of the fish from the time the experiment began until it was concluded.

Three fish died during the 1974 experiment. There was no food in their digestive tracts when examined after death. The dates of death, May 5 (two fish) and May 18 (one fish), strongly suggest that they died from tagging and handling injuries.

DISCUSSION

Since no fish were sacrificed during the 1974 experiment to examine their digestive tracts and since some food lodged in the gravel on the floor of the tanks so that all uneaten food could not be weighed, indirect evidence must be used to show that these fish actually ate the offered food. Such evidence was afforded from day to day when uneaten food was removed before introducing the next day's ration. At these times, there was always less corn and shellfish present in the tanks than had been

introduced. Additional indirect evidence was available from the aborted 1973 experiment where several of the fish found dead had food (both corn and ribbed mussel) in their digestive tracts. Moreover, had the fish not eaten, it must be assumed that in all cases the condition factor would have declined. This did not happen.

Since the 1973 experiment showed that winter flounders would eat corn under laboratory conditions and since the condition factors did not show any significant change regardless of diet from the beginning to the end of the 1974 experiment, the author concludes that the feeding of canned kernel corn up to 80 per cent by weight in the available diet did not alter the condition of the fish over a 35-day period. Canned kernel corn did not kill winter flounders. Thus, the use of canned kernel corn as chum for winter flounders does not appear to be harmful to these fish.

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GENERAL NOTES

LUNGWORMS IN FOXES IN NEW YORK[1]

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Sarcoptic mange and distemper have recently been recognized (Stone et al., 1974; Monson et al., 1976) as important factors in the mortality of foxes in New York State. The data reported here indicate that respiratory helminths (lungworms) are an additional such factor.

During 1973, the carcasses of 300 red foxes and gray foxes were submitted to the Wildlife Pathology and Physiology Unit by wildlife management personnel, trappers and the public. Of these specimens, 12 came from five eastern counties and the remaining 288 came from counties in the central part of the State (Figure 1). The carcasses were examined for lungworms by dissecting the trachea, bronchi and larger bronchioles. Numbers of worms and their location in the respiratory

Figure 1. Distribution of counties from which the red foxes and gray foxes examined were derived. Encircled numerals represent the number of specimens (both species) from each county.

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Table 1. Incidence of Lungworms in Foxes According To Three Independent Surveys

Foxes examined		Parasite	Foxes infested	
Species	Number		Number	Per cent
Present survey				
Red fox	211	*Crenosoma vulpis*	45	21.3
		Capillaria aerophila	87	41.0
Gray fox	89	*Crenosoma vulpis*	1	1.1
		Capillaria aerophila	25	28.0
Albany, Greene and Washington Counties*				
Red fox	190	*Crenosoma vulpis*	39	21.0
		Capillaria aerophila	66	36.0
Gray fox	89	*Crenosoma vulpis*	15	17.0
		Capillaria aerophila	6	7.0
England§				
Red fox	300	*Crenosoma vulpis*	1	0.3
		Capillaria aerophila	60	20.0

* From Goble and Cook (1942).

§ From Beresford-Jones (1961).

system were noted. Respiratory helminths were identified with the aid of descriptions by Davis and Anderson (1971) and Levine (1968).

The 300 specimens comprised 211 red foxes and 89 gray foxes (Table 1). Of the total, 133 (44.3 per cent) were infected with at least one of two species of nematode lungworm (*Capillaria aerophila* and *Crenosoma vulpis*). 35 (19 per cent) being infected with both species. Of the 211 red foxes, 45 (21.3 per cent) had infestations of *C. vulpis* in the bronchi and bronchioles, and a few of these had infestations in the trachea also. Only one (1.1 per cent) of the gray foxes was found to be infested with this parasite. The other species of lungworm, *C. aerophila*, was found in 87 (41.2 per cent) of the red foxes and 25 (28.0 per cent) of the gray foxes examined.

In cases of severe infection, both of these parasites are reported to cause bronchitis, bronchiolitis and bronchopneumonia (Levine, 1968; Davis and Anderson, 1971). Large numbers of the worms are said to occlude the bronchioles and result in dyspnea and coughing. Secondary bacterial pneumonitis often follows heavy infections. Histological sections of lung tissue taken from two red foxes heavily infected with *C. vulpis* showed bronchopneumonia accompanied by bronchitis and bronchiolitis.

Capillaria aerophila has a direct life cycle and its eggs, when released in the feces of its host, can become infective after a 28-day period of development in the soil (Levine, 1968). A fox needs only to ingest such eggs to become infected with this parasite. *Crenosoma vulpis* has an indirect life cycle and needs a snail as an intermediate host in order to reach its infective stage. Fourteen different species of snails can serve as intermediate hosts.

Some differences are apparent when the results of other studies on lungworms in foxes are compared with the data recorded in this survey. The incidence of *C. vulpis* in gray foxes in this study (1.1 per cent) was much lower than the 17 per cent reported by Goble and Cook (1942) for specimens from Albany, Greene and Washington counties in this State. Among red foxes, the corresponding percentages were 21.3 and 21.0, respectively, whereas this parasite was reported in only 0.3 per cent of red foxes in England (Beresford-Jones, 1961). Areas sampled, fox popu-

lation densities, availability and numbers of snails as intermediate hosts, and food preferences of foxes may all be factors affecting the incidence of this lungworm in foxes.

For *C. aerophila*, the incidence in the gray foxes examined in the present study was 28.0 per cent compared with 7.0 per cent for the sample from three eastern counties reported by Goble and Cook (1942). The latter authors also reported that none of 25 gray foxes from central New York was infested with this parasite. This difference in degree of infestation may be attributable to an increase in population density for the gray fox during the period 1942-1973. Among red foxes, the incidence of the parasite recorded in the present study (41.0 per cent) was not greatly higher than that (36.0 per cent) reported by Goble and Cook, but it was double that reported for England by Beresford-Jones (1961).

The data presented here demonstrate a relatively high frequency of lungworm infestation among adult foxes in New York. Morbidity and mortality in young pups may be still higher because of their small bronchi and bronchioles as well as a longer exposure time to the eggs of the parasites in fox feces near their den sites.

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BEHAVIOR OF MUSKELLUNGE FRY DURING YOLK ABSORPTION AND SWIM-UP[1]

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When muskellunge (*Esox masquinongy*) eggs from the State hatchery at Chautauqua Lake were transferred to the DeBruce Inland Fisheries Laboratory at Livingston Manor (N.Y.) in connection with a study of sac-fry mortality, an opportunity was afforded for observation of the fry during yolk absorption and swim-up. The eggs and fry were held in 350-gallon fiberglass tanks (5 feet long x 3 feet wide x 3 feet deep) at 62° and 72° F. Water flowed through the tanks continuously at a rate of 4.5 gallons per minute. Artificial light was supplied for 8 hours each day. Daily observations of the eggs and fry were made.

Upon hatching, the sac-fry were found dispersed on the bottom of the tank and lying on their sides, presumably due to their yolk sacs. Three or four days after completion of hatching, the fry began grouping in the water-inlet area of the tank. They remained clumped in a dense mass for 24-36 hours, then dispersed and took individual, scattered positions on the bottom of the tank. This dispersal was so dramatic that it gave the illusion of a decrease in fry numbers.

The gas bladder of most fish is initially filled by gulping atmospheric air at the time the yolk sac is adsorbed (Lagler et al., 1962). This act is part of the swim-up process that enables a muskellunge to start swimming with a functional gas bladder and feeding. Signs of impending swim-up began 24 hours after dispersal for fry in 72° F. water and 36 hours after dispersal for fry in 62° F. water. The process was characterized by continued efforts of the fry to break the surface film with their snouts. Some fry remained at the surface of the tank for up to 10 minutes, probably trying to take air into their gastrointestinal tracts. Undoubtedly, much energy was expended by fish attempting to fill their gas bladders in this manner. After varying lengths of time at the surface, the fry began sinking to the bottom, as would any sac-fry, but there was a suggestion of bouyancy that was not present before. Usually the fry would continue to fall toward the bottom until they could cling (in an upright position) to a substrate with which they came in contact. Fry that reached the bottom of the tank generally came to rest in an upright position, in contrast to sac-fry which lay on their sides. Microscopic examination of these "resting" fry showed air in different parts of the digestive tract, as well as partially filled gas bladders. The fry tended to "rest" in an upright position for indefinite lengths of time, then floated away from the substrate and began swimming. One group remained in this "resting" state for 8 hours before taking on normal swimming activities.

To verify the apparent need to ingest air, 15 sac-fry were placed in a 1-liter jar which was covered with cheesecloth and sunk to the bottom of a 350-gallon tank. After other fish in the tank were swimming, these specimens were either dead or still lying on their sides, indicating a definite need for atmospheric air.

The time lapse from the initial signs of swim-up until all fry were swimming was 72 hours for those held at 62° F. and 48 hours for those held at 72° F. During these periods it was possible to identify fry in three different stages: sac-fry lying on their sides on the tank bottom; fry "resting" on the bottom or clinging to the sides of the tank (presumably having already surfaced and gulped air); and, finally, swimming fry.

At times throughout the yolk-absorption period, especially shortly after hatching, sac-fry became associated with the surface of the water and appeared to float there. This was a surface-film phenomenon, and, if these fry were disturbed, they sank as sac-fry and not as "resting" fry.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.

THEORETICAL CONSIDERATION OF THE CAUSE OF GAS-BUBBLE DISEASE IN FISH IN A HEATED EFFLUENT

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The occurrence of gas-bubble disease in fish in the heated effluents from power plants has been well documented. The cause of the disease has been ascribed to oxygen and nitrogen supersaturation of the heated discharge (Adair and Hains, 1974; Miller, 1974). It is the author's hypothesis that gas supersaturation is a necessary condition but that the disease is triggered by cold stress.

Osmoregulatory failure occurs in cold-stressed fish (Block, 1974). Variations in plasma proteins, osmolarity, glucose, chloride, and hematocrit values in fish after exposure to acute cold stress should be sufficient to release dissolved gases in the blood from solution. All reported incidents of gas-bubble disease at thermal-electric stations have occurred in the winter when the possibility of cold stress existed.

Field observations (Miller, 1974; Demont and Miller, 1971) have indicated that the frequency of gas-bubble disease varies greatly. A possible cause of this wide range of occurrence is the relationship of natural fluctuations in ambient winter water temperatures to the operating regime of the associated thermal-electric stations. These variations in water temperature affect the probability of an organism, acclimated to temperatures of the discharge plume, leaving the plume long enough to become cold stressed.

Observation of apparently healthy tiger barbs (*Barbus* spp.) subjected to cold stress showed a high incidence of pop-eye, a symptom of gas-bubble disease. Experimentation is needed to determine which physiological response actually results in the release of gas from solution. Without this basic knowledge, attempts to alleviate the problem may be unnecessarily expensive.

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AN UNUSUALLY LARGE STRIPED SEAROBIN FROM LONG ISLAND SOUND, NEW YORK[1]

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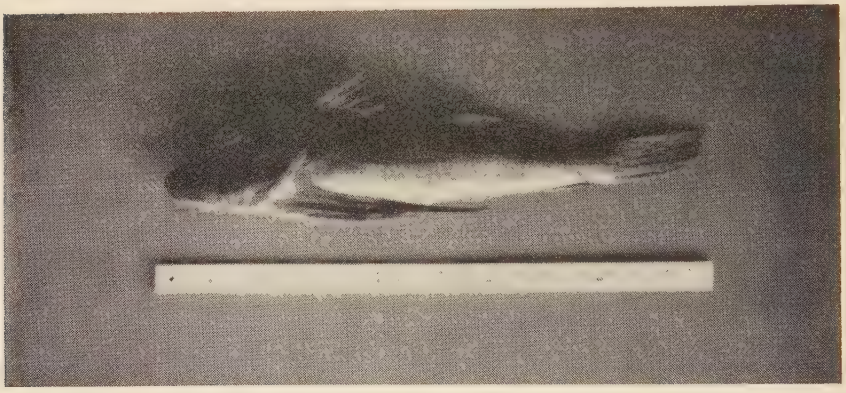
On August 12, 1975 an angler, Joseph Gioffre of Stony Brook (N.Y.), brought a searobin (*Prionotus evolans*) to the local office of the Department for verification of identification. He had caught the fish, which measured 485 millimeters in fork length and weighed 1,395 grams, about 0.9 kilometer north of Crane Neck in Long Island Sound. The striped searobin is common in Long Island Sound



Striped searobin, 485 millimeters in fork length, taken in Long Island Sound, New York. (Rule represents 500 millimeters)

(Thomson et al., 1971) and ordinarily the catch of one would not be noteworthy. However, Mr. Gioffre's fish was extraordinary because of its large size.

A literature search revealed that 18 inches (457 millimeters), or less in some cases, has been cited as the maximum size of the striped searobin (DeKay, 1842; Bean, 1901; Nichols and Breder, 1926; Hildlebrand and Schroder, 1928; Breder, 1948; Bigelow and Schroeder, 1953; Thomson et al., 1971). The largest striped searobins the author could verify were a 470-millimeter specimen from Orient Harbor, Ner York (Latham, 1964) and a 415-millimeter (fork length) specimen reported by McEachran and Davis (1970) to have been taken in the "Chesapeake Bight". Thus, Mr. Gioffre's fish appears to be the largest striped searobin whose length has been verified.

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OCCURRENCE OF THE OPOSSUM ON THE TUG HILL PLATEAU

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The opossum (*Didelphis marsupialis virginiana*) has been extending its range into upstate New York since the 1930's, and within the past two decades it has begun to appear on all sides of the Tug Hill plateau. This area lies between Lake Ontario and the Black River valley, mostly in southwestern Lewis County but extending somewhat into northwestern Oneida County, northeastern Oswego County and southeastern Jefferson County. The plateau proper occupies several hundred square miles and, in general, is between 1,500 and 1,900 feet in elevation, although parts of the east-central portion are over 2,000 feet. The growing season is short, winters are severe and the snowfall is the heaviest in the State. Most of the reported observations of opossums, however, have been at elevations of less than 1,000 feet (Connor, 1964) and only marginal to the plateau itself, although it seems reasonable to conclude that the species is becoming a part of the local fauna up to this elevation.

Two other recent records are of interest. On November 21, 1975, a trapper caught a large female opossum in a conibear trap set for fisher along the old railroad bed leading to the former hamlet of Page northwest of Turin in Lewis County. The elevation in this area is between 1,900 and 2,000 feet. There is also a report, that the author considers reliable, of an opossum seen crossing a road in the vicinity of the fire tower on Gomer Hill (2,100 feet and the highest point on the plateau) in the summer of 1973. Examination of the animal taken in November 1975 revealed no evidence that the tips of the ears or tail had been frozen as commonly happens to opossums living in upstate New York. The same was true of the specimen found dead on the highway near Cranberry Lake in St. Lawrence County on February 20, 1971 as reported by Severinghaus (1975).

One can only speculate as to the circumstances that led to the presence of these opossums where they were observed on Tug Hill. Perhaps they did not spend the preceding winter there, or perhaps the mild winters of the previous several years allowed them to winter at higher elevations than usual, possibly using abandoned farm buildings as shelter. Nevertheless, because of the usually severe winter conditions, it seems unlikely that the opossum, which must forage for food all year, will become established as a resident population on the plateau proper.

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